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INVESTIGATION OF NORTH BRANCH POTOMAC RIVER

REPORT ON BENEFITS TO POLLUTION ABATEMENT FROM LOW-FLOW AUGMENTATION ON THE NORTH BRANCH POTOMAC RIVER

ROBERT A. TAFT SANITARY ENGINEERING CENTER
CINCINNATI, OHIO

PREPARED FOR
CORPS OF ENGINEERS, WASHINGTON, D. C.

AUGUST 1957

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Investigation of
NORTH BRANCH POTOMAC RIVER

Report on Benefits to Pollution Abatement from Low-Flow Augmentation on the North Branch Potomac River

Prepared by

U. S. Department of Health, Education, and Welfare
Public Health Service
Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

at the request of and in cooperation with the
District Engineer, Washington District, Corps of Engineers

August 1957

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The success of a survey of this type depends to a large extent upon the cooperation of other Federal agencies, State and local agencies, and industrial firms in the region studied. This survey was aided materially by the extensive cooperation and assistance obtained in the Cumberland area.

The Allegany County Commissioners, through Mr. Walker Chapman, County Engineer, provided parking space and the utilities necessary to operate the trailer laboratory.

Allegheny Ballistics Laboratory and Frostburg State Teachers College provided an unfailing supply of distilled water.

Stream discharge data were provided as needed by Mr. E. L. Mohler of the United States Geological Survey office in Cumberland.

Mr. Frank Powers and his staff at the Maryland Bureau of Mines Office in Westernport, Md., provided information on the sources of acid mine drainage in western Maryland and conducted representatives of the Public Health Service on a tour of the streams carrying mine drainage.

Mr. Paul McKee, Director of the Maryland Water Pollution Control Commission, supplied preliminary information on problems in the region and permitted data from his files to be used in this study.

Mr. Glenn Hawkins, the regional representative of the Maryland Water Pollution Control Commission, aided by introducing representatives in the Luke-Cumberland vicinity.

Mr. George L. Hall of the Maryland Department of Health provided data from his files about problems in the Cumberland area.

Mr. Ellis S. Tisdale, Director of the Interstate Commission on the Potomac River Basin, offered information from his files for planning this program.

Mr. George M. Griffiths, Chief Sanitary Engineer of the West Virginia Pulp and Paper Company at Luke, Md., was most cooperative in providing information about pollution abatement plans for the plant, the current waste discharges, and analytical information from tests the Company has conducted on the river.

The Celanese Corporation of America, the Kelly-Springfield Tire Company, the Potomac Edison Company, and the Pittsburgh Plate Glass Company also provided information on their operations for use in the study.

INTRODUCTION

This report presents the results of an investigation of water quality and pollution in the North Branch of the Potomac River and its tributaries. This survey was requested by the Corps of Engineers to aid in developing a comprehensive water resources plan for the Potomac River Basin.

Authority for the survey was granted by the Washington District, Corps of Engineers, in a letter dated August 13, 1956, accepting and approving the plan of study outlined in a letter from the Public Health Service Regional Office III dated May 23, 1956.

The scope of this study, as set forth by the Public Health Service letter referred to in the preceding paragraph, includes "...reconnaissance of sources of municipal and industrial pollution; assembly and review of available information on these sources of waste and their effects on the stream, determination of water quality objectives for the stream affected by wastes (in collaboration with appropriate State agencies); assembly of stream flow records and analysis of low-flow conditions; special stream and waste surveys where needed to supplement existing information in identifying characteristics...; investigation of water quality, particularly in relation to acid mine drainage and suitability after storage as a source of water supply; estimates of desirable minimum stream flows in combination with reasonable treatment and control measures for existing and contemplated future population and industrial development conditions; estimate of benefits which might accrue from provision of low-flow regulations; and miscellaneous related features.

The Corps of Engineers has requested that, in view of the over-all purpose of their study, benefits not be limited to those which could be estimated through adherence to criteria established by the Bureau of the Budget, but should include all reasonable benefits attributable to the proposed reservoirs. This has been done to the full extent of the available information.

Studies on the North Branch of the Potomac River have been conducted by several agencies during recent years. These were directed primarily toward measuring effects of industrial wastes in the Luke-Cumberland area and of municipal sewage in the Cumberland area. The most recent and most thorough work on the industrial waste problems in the region was presented by Fuhrman in a report of the Interstate Commission on the Potomac River Basin. Excellent bacteriological data were obtained in the Cumberland vicinity by the Maryland Department of Health. The West Virginia Pulp and Paper Company at Luke, Md., continues to sample the river above and below its plant. These three sources of information have supplemented the measurements taken by the 1956 field staff. Comparison of this recent data with that of Fuhrman showed how the degree of pollution has altered in extent and magnitude since his study. Since the field survey did not include bacteriological analyses, pollution from human wastes in the river below Cumberland was estimated from the data of the Maryland Department of Health. Annual fluctuations in acid-mine-waste discharge and in temperature were established from the regular measurements by the paper mill.

From the new data, evaluations based on previous data, and comparisons indicating the changes to be expected, conclusions have been drawn about the future water quality of the North Branch. The effects of low-flow augmentation under these projected conditions have been calculated for any or all of three possible sites for new dams to be situated on the Stony River, the Savage River and the North Branch.

SUMMARY

(1) The waters of the North Branch at Cumberland would be costly to treat for a municipal supply. Therefore, Cumberland and other communities in this area will have to look to tributaries such as Savage River for larger additional water supplies for municipal use. The North Branch is now used as a source of municipal water supply only by Luke, which is supplied from the West Virginia Pulp and Paper Company treatment plant. The Piedmont-Westernport area is supplied from the Savage River Dam with water requiring minimal treatment. Keyser and Frostburg have municipal reservoirs on small streams.

(2) Industrial cooling and process water is now furnished by the North Branch. The West Virginia Pulp and Paper Company uses North Branch water exclusively and has a complete water treatment plant. The Celanese Corporation, Kelly-Springfield Tire Company, and Potomac Edison Company use the North Branch as a source of cooling water, getting their process water, as needed, from the City of Cumberland. The Pittsburgh Plate Glass Company will draw all its process and cooling water from the North Branch, treating it as required for individual processes.

(3) Flow in the North Branch is regulated by two dams: (a) the Stony River Dam, owned and operated by the West Virginia Pulp and Paper Company, (b) the Savage River Dam, built by the Corps of Engineers and operated by the Upper Potomac River Commission. The Stony River Dam has relatively little effect on the flow at Luke; the minimum weekly flow occurring once in ten years is 18 cfs in the North

Branch immediately above the confluence of the Savage River. The Savage River Dam is regulated so as to provide continuous minimum flow of 93 cfs in the North Branch at Luke.

(4) Acid mine drainage is the principal pollutant in the North Branch above Luke. That reach is acid virtually all the time, and is extremely acid during periods of low-flow. Below Luke, acid mine waste is not a problem on the North Branch since the alkaline paper mill waste effectively neutralizes it. Georges Creek, discharging below Luke, was also found to have a high acidity as a result of this type of pollution. Wills Creek, discharging at Cumberland and reported to contain large amounts of this waste, had no measurable amount.

(5) The Fairfax Coal Washery discharges large quantities of coal fines to the North Branch; this waste discolors the river for many miles downstream of the plant, but the color effects are fairly well dissipated before Luke is reached. The large amounts of suspended solids present in the waste also inhibit aquatic life in the polluted reach.

(6) The West Virginia Pulp and Paper Company discharges paper mill wastes containing 47,000 pounds per day of B.O.D. (5-day, 20°C.) and 106,000 pounds per day of suspended solids into the North Branch. This waste grossly pollutes the river far downstream.

(7) The Celanese Corporation discharges about 10,000 pounds per day of B.O.D. (5-day, 20°C.) This waste plus that remaining from upstream keep the river in its highly polluted state above the Cumberland sewage outfall.

(8) Municipal sewage enters the North Branch from every community along its banks. Waste from the smaller communities is not significant in the much greater load of industrial waste present. Cumberland contributes the greatest sewage load, about 6,800 pounds per day of B.O.D. (5-day, 20°C.)* This load enters the North Branch long before the wastes from the industrial plants are assimilated; the resulting combined organic loads were not assimilated during the survey period until the river reached the vicinity of Oldtown.

(9) Major changes are anticipated in the waste loads in the North Branch. The City of Cumberland will begin primary treatment of its sewage during 1957. This should reduce the organic waste load imposed by Cumberland by 35 per cent. The West Virginia Pulp and Paper Company is planning to double the plant production capacity and to install waste treatment facilities for reducing the total waste load to 16,000 pounds of B.O.D. and 34,000 pounds of suspended solids per day. These immediate changes should result in an improved water quality in the North Branch. Increased industrial activity and increased population will, however, continually add to the pollution load on the stream.

(10) Three sites are considered for possible construction of impounding reservoirs to increase minimum flow in the North Branch. These are, in order of decreasing quality of impounded water: (a) On the Savage River above the present impoundment, (b) On the Stony

---

* Based on 0.17 pounds per capita per day.

River below U. S. Route 50, (c) On the North Branch above Bloomington. The New Savage River Dam would develop 45 cfs, Stony River Dam 60 cfs, and the North Branch Dam 134-171 cfs additional minimum flow at Luke over the 93 cfs presently provided.

(11) Abundant and varied aquatic life, fishing, boating, swimming, and all other recreational uses would develop in the Savage River and Stony River impoundments. There would be some inhibition of aquatic life in the North Branch impoundment due to the acidity of the reservoir water. The proposed North Branch impoundment would be a decided improvement upon existing conditions and would probably support less sensitive fish life, and provide recreation such as boating and water skiing.

(12) The use of the North Branch site would probably involve some damage to submerged concrete and metal structures unless adequate protective measures are taken.

(13) The effects of these reservoirs in reducing the extent of pollution by acid mine drainage is of extreme importance, since dilution of the acid is the only known practical direct means of reducing this type of pollution. The effect of waters released from each of these sites upon the reduction in concentration of acid mine drainage will be dependent upon the alkalinity of the reservoir waters and upon the location of the dam. A dam on the North Branch at Bloomington would be most effective at smaller flow augmentation because the acid water discharged above the dam at times of low-flow would be stored in the reservoir while an equivalent discharge of less

acid water would come from the vicinity of the dam. Each of the other two dams would affect the acidity of the North Branch by dilution and partial neutralization of the acid water of the North Branch; Savage River water would be more effective than Stony River water because of its higher alkalinity.

(14) Effective neutralization of the acidity in the stream occurs at Luke, caused by the very high alkalinity of the paper mill wastes. The effects of increased discharge below Luke are independent of the source of the augmenting discharge.

(15) Benefits attributable to the reduction of the effects of acid mine drainage have been estimated on the basis of reduction in water treatment costs at the West Virginia Pulp and Paper Company only. Annual benefits are estimated as $25,000 for the Savage River site, $23,000 for the Stony River site, and $58,000-63,000 for the North Branch site.

(16) Decreases in temperature of cooling water at the West Virginia Pulp and Paper Company would result in increased efficiency of condensing and cooling operations. This would provide a maximum annual benefit equivalent to $120,000 for the Savage River Dam and $246,000 for the North Branch Dam. No benefits would exist due to the Stony River Dam because its great distance upstream from the plant would permit the discharged water to regain temperature equilibrium with the air. The reimbursable benefits of temperature are estimated at $62,000 and $125,000 annually for the same two dams.

(17) If the criteria of the Interstate Commission on the Potomac River Basin for Class D streams are used as an objective for the North Branch below Luke, waste treatment will be required at the West Virginia Pulp and Paper Company, the Celanese Corporation, and at the City of Cumberland in addition to those facilities presently planned if present minimum flows are maintained. Increasing the minimum continuous discharge in the North Branch to 1,000 cfs at Luke would permit the substitution of dilution for additional waste treatment. Such a degree of flow augmentation is not possible with the reservoirs under consideration. It is recommended that as high a degree of flow augmentation be provided as is economically feasible.

(18) Benefits to the North Branch below Luke have been attributed to the abatement of pollution from industrial and municipal sources. In estimating pollution abatement benefits it is assumed that primary treatment of wastes is always necessary. Flow augmentation may, however, substitute for intermediate, secondary or tertiary treatment. In such a case the annual benefit credited to the flow increase is the difference in annual cost between the necessary higher degree of treatment and primary treatment to obtain the same water quality. If secondary treatment is necessary in any case the annual benefit is the annual cost decrease between the amount of secondary treatment required at the augmented flow and the amount required at present minimum flows. These benefits are presented in Table 17 and in Figure 15.

(19) In addition to these tangible benefits, there are numerous intangible values of widespread general benefit. Typical benefits would be increased aquatic life, increased recreational uses,

and better aesthetic values of the river basin. Furthermore, increased flow in the North Branch would have a favorable effect in improving water quality downstream and making it more suitable for storage in proposed water supply reservoirs. While an increase of 200-300 cfs at minimum flow in the North Branch alone would have little effect on pollution abatement far downstream, as part of an over-all plan for low-flow augmentation in the Potomac River, increased flow in the North Branch would contribute its proportional part to pollution abatement in the Washington vicinity. The calculation of such benefits to the Washington area must wait upon a detailed study of conditions downstream of the region considered here.

(20) It is recommended that additional field work be done after the Cumberland sewage treatment plant is in operation, and again after the waste treatment plant at Luke is in operation, in order to evaluate in detail the effects of these installations on water quality.

(21) All construction cost figures were adjusted to the Engineering News-Record (1913 = 100) Index for January 1957 (707.9). The costs of chemicals were based on market quotations of February 11, 1957.

CONCLUSIONS

(1) The North Branch below Luke is costly to treat for use as a municipal water supply or as industrial process water. It is usable for industrial cooling water below Luke and for limited industrial process water some distance below Cumberland.

(2) Any large industrial water user locating on the North Branch watershed would have to use the North Branch as a source of water supply. In its present polluted condition, the North Branch could easily prevent consideration of its valley as a potential plant location.

(3) Present pollution abatement plans are not sufficient to change this situation to any large extent with present minimum flow conditions.

(4) Waste treatment sufficient to permit the North Branch to meet the Class D stream standards (minimum sanitary quality) of the Interstate Commission would be extremely expensive with present minimum flows.

(5) Reduction of acid mine drainage pollution by any known conventional methods except dilution is impractical.

(6) Flow augmentation in the North Branch could attain pollution abatement results not attainable in any other practical way. Increased flows in the North Branch would reduce the extent of pollution by acid mine drainage and reduce the amount of waste treatment necessary to attain water quality compatible with Class D stream criteria of the Interstate Commission.

(7) Tangible benefits of increased flow in the North Branch result from decreased waste treatment costs, decreased water treatment costs and decreased power generating and pumping costs. These benefits range from $553,000 per year for 60 cfs increase from the Stony River to $1,450,000 per year for a total of 276 cfs increase from the Savage River, Stony River, and North Branch if it is assumed the Interstate Commission criteria are to be met. If the Maryland State Department of Health requirements for sewage treatment at Cumberland are regarded as an adequate minimum, then the total reimbursable benefits are estimated to range from $43,000 annually for 60 cfs from the Stony River to $267,000 annually for 171 cfs increase in minimum flow from the North Branch.

(8) Intangible benefits due to increased aquatic life, increased recreational utilization of the watershed, and better aesthetic values of the basin would also result from flow augmentation of the North Branch.

(9) It is recommended that as much low-flow augmentation be provided as is economically feasible.

DESCRIPTION OF THE NORTH BRANCH WATERSHED

Geography

The North Branch of the Potomac River rises in the Allegheny highlands of the Appalachian Mountains and forms the southern boundary of Maryland and the northern boundary of West Virginia. It drains Allegany County and part of Garrett County in Maryland, parts of Somerset and Bedford Counties in Pennsylvania, and Grant and Mineral Counties in West Virginia. The total drainage area contains 1,384 square miles and consists largely of a series of heavily wooded, steep valleys and mountains. The river reach studied in this survey is shown in Figure 1.

Throughout its length the North Branch is a series of pools interrupted by shallow riffles and cascades. It rises at an elevation of 3,180 feet and has fallen to an elevation of about 930 feet at Luke, Md., a drop averaging almost 50 feet per mile. From this point to Cumberland the slope is much less, averaging about 11 feet per mile; from Cumberland to the confluence with the South Branch the slope is about 4 feet per mile.

Rainfall on the North Branch watershed amounts to about 40 inches annually; 30 inches of accumulated snow and temperatures of -10 degrees Fahrenheit are frequent. In spite of the heavily wooded nature of the watershed, runoff is extremely rapid; consequently, the North Branch has a reputation as a very "flashy" stream. Figure 2 graphs some typical flow variations, but over a period of years some very wide extremes have been reported. At Kitzmiller, Md., gaging records for four years show a minimum flow of 5.8 cfs and a maximum flow of 8,510 cfs. At Pinto, Md., the records of fifteen years show extremes of 31 cfs and 45,900 cfs and an average flow of 872 cfs. Gages immediately below Cumberland recorded for twenty-four years an average flow of 1,220 cfs and extremes of 38 cfs and 88,200 cfs. The Savage River Dam has exercised some control over low-flows from Luke downstream since it was put in operation in 1952. This dam is operated to maintain a minimum flow of 93 cfs in the North Branch at Luke. Some low-flow regulation is also provided by the Stony River Dam, owned by the West Virginia Pulp and Paper Company.

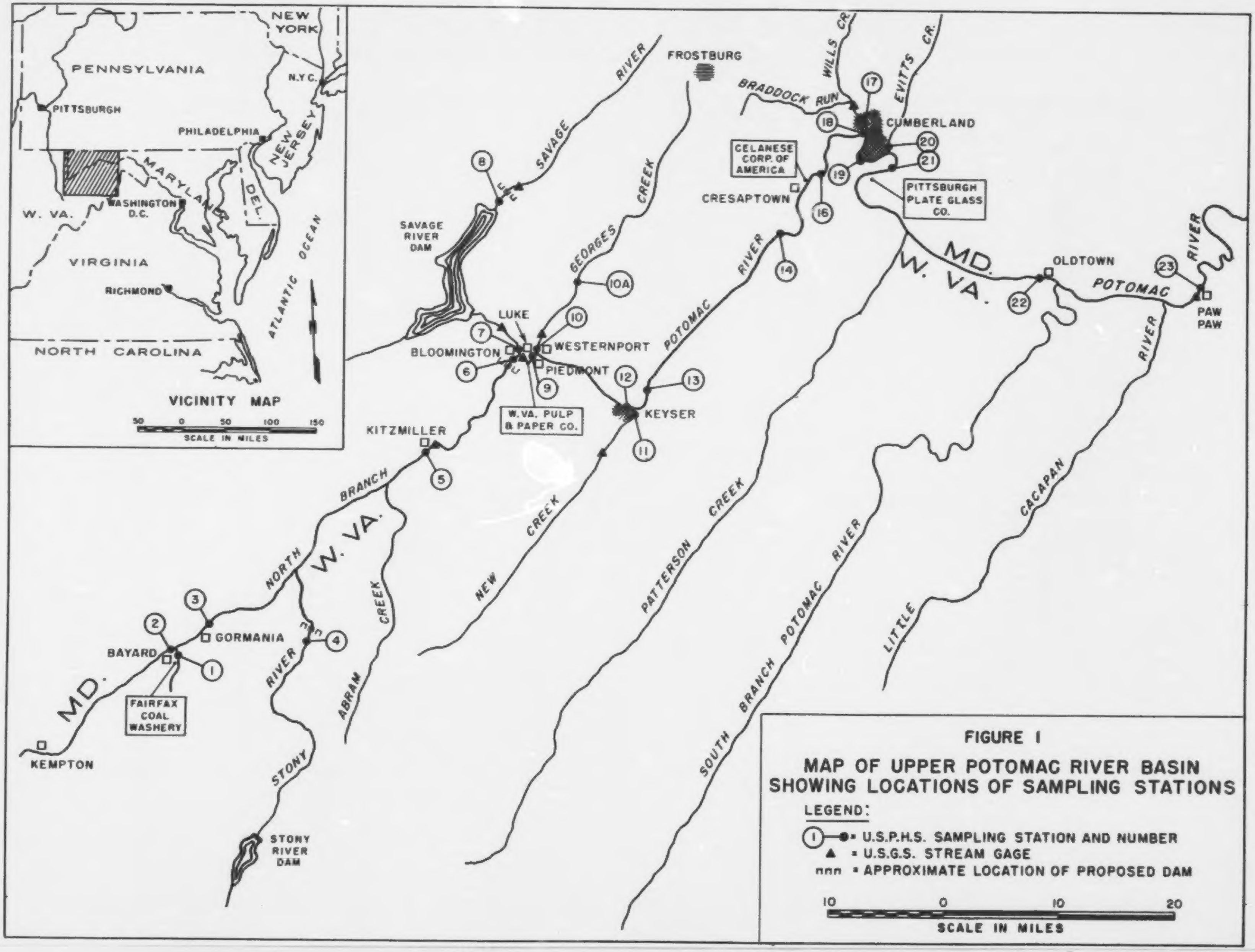
Economics

The population of the North Branch watershed is about 100,000. The bulk of the urban population, about 50,000, is concentrated in and around Cumberland, Md. Table 1 presents a population summary of the major communities on the watershed.

Mining has been one of the primary means of livelihood in the past; many of the small communities grew up in the vicinities of mining operations. Many mines have been worked out, and the families remaining around these abandoned mines subsist either by farming, or industrial employment.

In the Luke-Piedmont-Westernport area, the West Virginia Pulp and Paper Company is the primary source of employment; in the Cumberland area the Celanese Corporation, Kelly-Springfield Tire Company, Potomac Edison Company and the railroads are major employers. Keyser, W. Va., is an important railroad maintenance depot.

There is a labor surplus in the Cumberland area at present; this


VICINITY MAP
NEW YORK
PENNSYLVANIA
PITTSBURGH
PHILADELPHIA
N.Y.C.
NEW JERSEY
MARYLAND
DEL.
WASHINGTON D.C.
W. VA.
VIRGINIA
RICHMOND
NORTH CAROLINA
ATLANTIC OCEAN
50 0 50 100 150
SCALE IN MILES
SAVAGE RIVER
FROSTBURG
BRADDOCK RUN
WILLS CR.
EVITTS CR.
CUMBERLAND
CELANESE CORP. OF AMERICA
CRESAPTOWN
PITTSBURGH PLATE GLASS CO.
SAVAGE RIVER DAM
GEORGES CREEK
LUKE
BLOOMINGTON
WESTERNPORT
PIEDMONT
W.VA. PULP & PAPER CO.
KEYSER
POTOMAC RIVER
MD.
W. VA.
OLDTOWN
POTOMAC
RIVER
PAW PAW
KITZMILLER
NORTH BRANCH
NEW CREEK
PATTERSON CREEK
SOUTH BRANCH POTOMAC RIVER
CACAPAN RIVER
LITTLE
ABRAM CREEK
STONY RIVER
STONY RIVER DAM
BAYARD
GORMANIA
FAIRFAX COAL WASHERY
KEMPTON
1
2
3
4
5
6
7
8
9
10
10A
11
12
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14
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19
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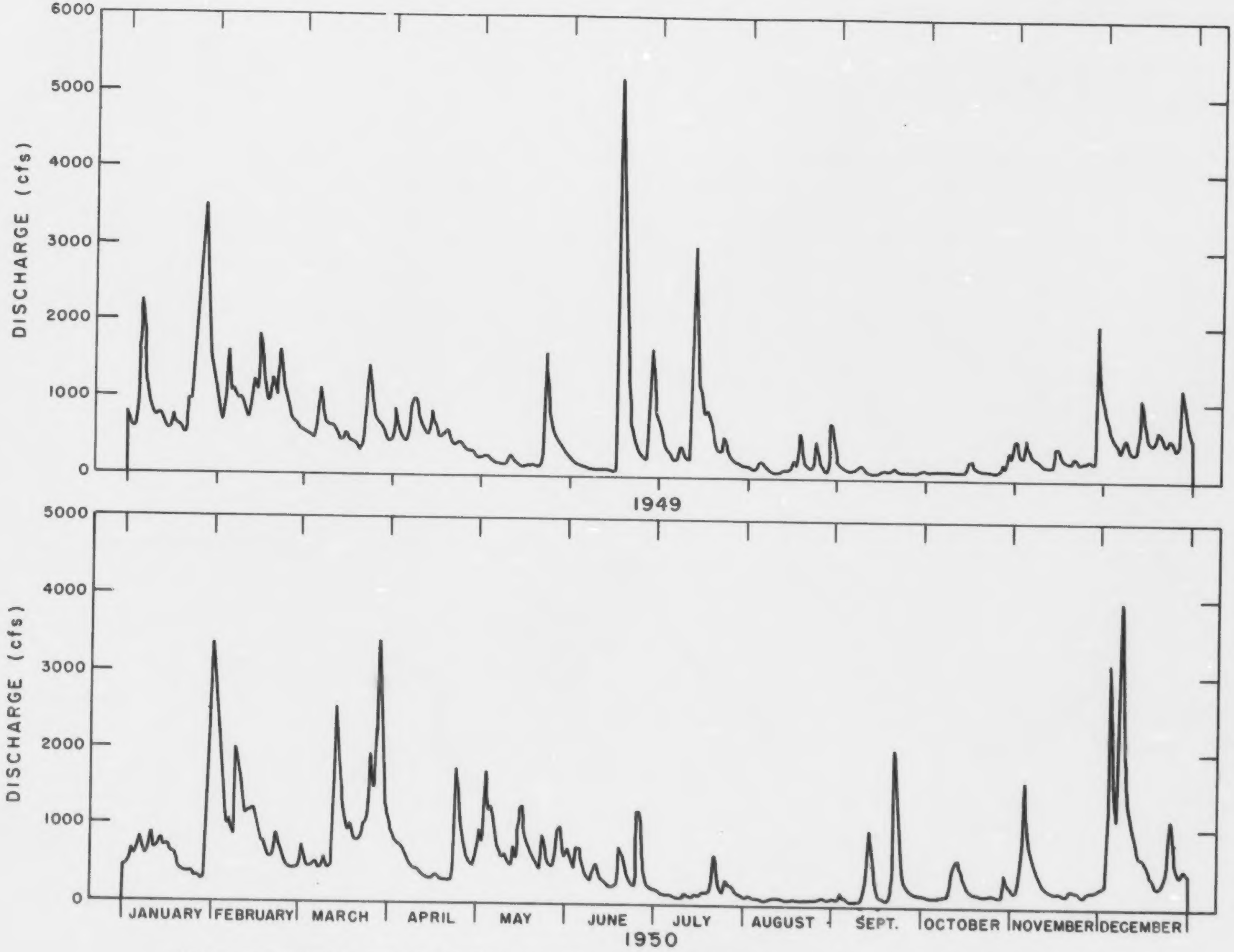
21
22
23
LEGEND:
① = U.S.P.H.S. SAMPLING STATION AND NUMBER
▲ = U.S.G.S. STREAM GAGE
nnn = APPROXIMATE LOCATION OF PROPOSED DAM
10 0 10 20
SCALE IN MILES

FIGURE I

MAP OF UPPER POTOMAC RIVER BASIN SHOWING LOCATIONS OF SAMPLING STATIONS



HYDROGRAPH OF NORTH BRANCH POTOMAC RIVER AT BLOOMINGTON
FOR TWO TYPICAL YEARS OF RECORD
FIGURE 2

TABLE 1

Centers of Population on the North Branch Watershed

Community	1950 Population Total	Sewered (1)	% Sewered
On North Branch, Potomac River:			
Bayard, W. Va.	589	0 (2)	0
Kitzmiller, Md.	652	0 (2)	0
Luke, Md.	820	750	92
Westernport, Md.	3431	3400	99
Piedmont, W. Va.	2565	2300	90
Keyser, W. Va.	6347	4650	73
Cresaptown, Md.	900	0	0
Cumberland, Md.	37679	36000	95
Ridgeley, W. Va.	1754	930	53
Total	54737	48030	
Georges Creek Watershed:			
Frostburg, Md.	6876	5000	73
Midland, Md.	889	620	70
Lonaconing, Md.	2289	1880	82
Barton, Md.	695	480	69
Total	10749	7980	
Wills Creek Watershed:			
Narrows Park, Md.	2022	0	0
LaVale, Md.	4257	0	0
Eckhart Mines, Md.	1816	0	0
Mount Savage, Md.	2094	0	0
Corriganville, Md.	602	0	0
Ellerslie, Md.	1813	0	0
Hyndman, Pa.	1322	1322	100
Total	13926	1322	
Grand Total	79412	57332	

(1) Except where otherwise indicated, data from records of the Interstate Commission on the Potomac River.

(2) Information from local sources.

situation may be alleviated to some extent by expansion at the West Virginia Pulp and Paper Company and by the opening of a Pittsburgh Plate Glass Company plant near Cumberland.

The region has abundant natural resources of limestone, dolomite, glass sand, clay, hard and soft woods, and some coal and granite. The upper part of the watershed has an annual rainfall of about 40 inches. The drainage area of this section is about 500 square miles. These facts indicate that a potentially abundant water supply exists if the run-off were controlled by a system of flow regulating reservoirs.

SURVEY PROCEDURES

Preliminary Investigation

The Potomac River Basin as a whole has been studied several times, and the Luke-Cumberland region has received particular attention from the Maryland Department of Health, the Maryland Water Pollution Control Commission, the Interstate Commission on the Potomac River Basin, and the several industries located there. Information obtained by these agencies was made available to representatives of the Public Health Service for their consideration and use in this study.

Review of these data and a two-week reconnaissance of the region established the need for a detailed survey of the river in its present condition. Factors requiring more specific information were: (1) the acid-mine-drainage problem, (2) the control of low-flow conditions by the Savage River Dam, (3) changes in industrial plant operations, (4) planned modifications in the Cumberland sewage treatment system, and (5) a relocated dam at Cumberland. To supply this information, a sampling and analysis program was outlined which embodied procedures used in previous surveys and also included some additional tests to give a more complete picture of stream conditions.

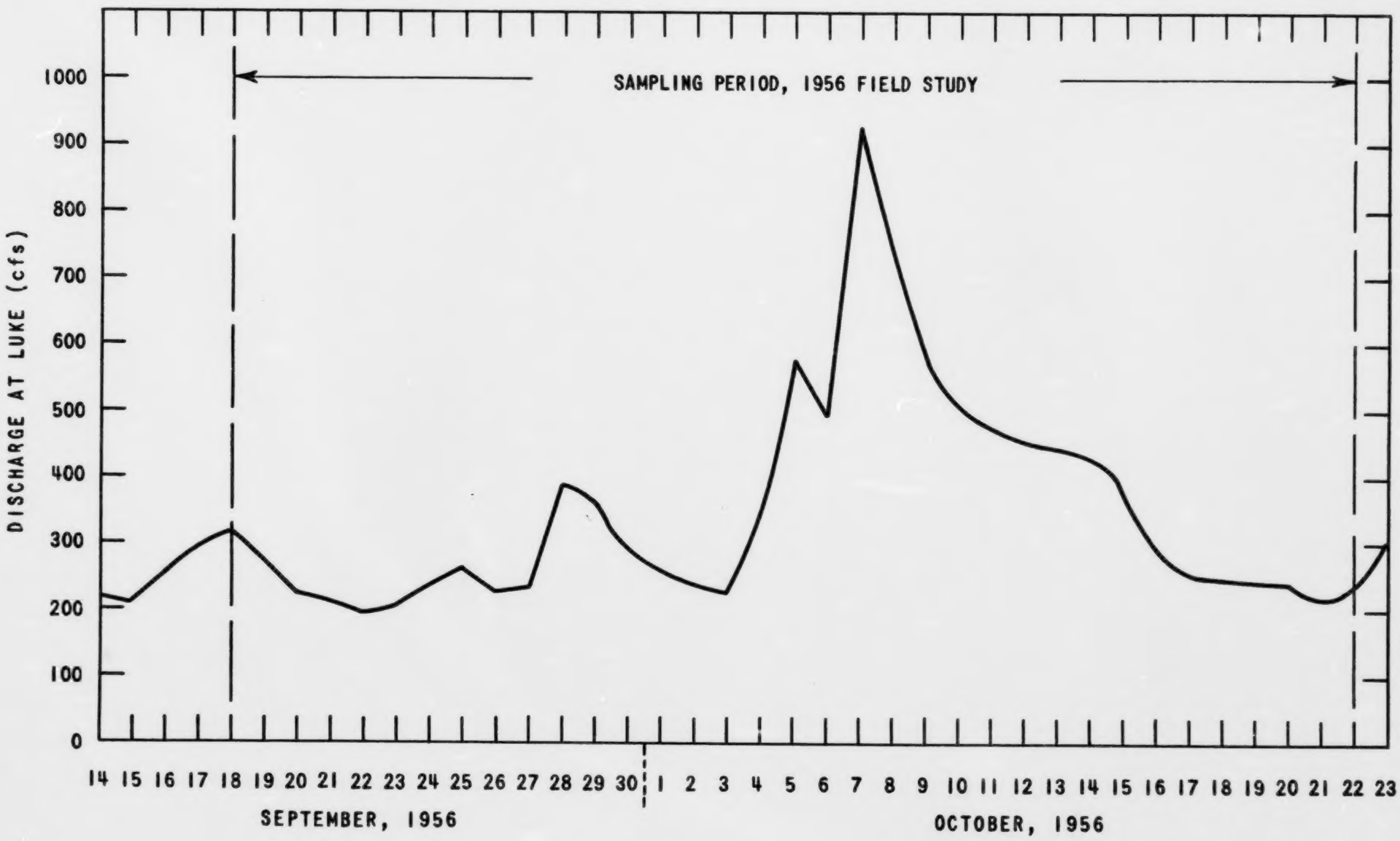
Sampling Procedures

Twenty-three sampling stations on the North Branch and its significant tributaries were selected, and a schedule was arranged for sampling all stations at least five times and the more significant locations a minimum of seven times. Provisions were also made for obtaining 24-hour composite samples at points which would be subject to fluctuations in waste load. The sampling stations are located in Figure 1 and descriptions of these places are given in Table II.

A Sargent sampler was used, and all samples were taken by Public Health Service personnel. The samples for dissolved oxygen determinations were fixed as they were collected and were titrated later in the laboratory. Samples for other analyses were kept cool until they were delivered.

Discharge measurements for most of the sampling stations came from the U. S. Geological Survey. Figure 3 shows the variations in flow which occurred at their Luke gage during the survey; porportionate fluctuations occurred at other stations. Staff gages were erected at Sampling Stations 1 and 20, but the gage at Station 20 was destroyed by vandals so the flows for that location are estimates derived from intermittent discharge measurements. A staff gage was also placed in the Cumberland sewage outfall for use in the composite sampling program.

Composite sampling was used at several locations, at two of them more than once. Three composite samples of the river above and below the paper plant at Luke were obtained on three different occasions; the same procedure was followed each time. A sample was taken at Station 9 every half hour for a 24-hour period, every sample being the same volume; these were combined in a large polyethylene container. Concurrently, similar samples were taken at Stations 6 and 7 but every two hours instead of every half hour. These were put in two separate containers, one for each station. No samples having volumes proportional to flow were collected, since the sampling was done while the river flow remained fairly constant.



FLOW IN THE NORTH BRANCH - SEPTEMBER AND OCTOBER, 1956

Figure 3

TABLE 2

Locations and Descriptions of Sampling Stations

Station No.	Stream	Town	Location	River Miles from Source	Drainage Area (sq. miles)
1	Buffalo Creek	Bayard, W. Va.	Highway Bridge, W. Va. Rt. 90	-	-
2	North Branch Potomac River	Bayard, W. Va.	Highway Bridge	11.1	-
-	North Branch Potomac River	Bayard, W. Va.	Confluence, Buffalo Creek	11.3	-
3	North Branch Potomac River	Gormania, W. Va.	Old Bridge, Downstream of US. Rt. 50 Bridge	13.5	-
4	Stony River	-	Highway Bridge, US. Rt. 50	-	-
-	North Branch Potomac River	-	Confluence, Stony River	19.4	-
-	North Branch Potomac River	-	Confluence, Abrams Creek	26.5	-
5	North Branch Potomac River	Kitzmiller, Md.	Highway Bridge, Md. Rt. 38	28.2	225
6	North Branch Potomac River	Bloomington, Md.	Highway Bridge	44.7	287
-	North Branch Potomac River	Bloomington, Md.	Confluence, Savage River	44.8	-
7	Savage River	Bloomington, Md.	Highway Bridge, Md. Rt. 135	-	-
8	Savage River	-	Savage River Road, Roadside Park above Lake	-	-
-	North Branch Potomac River	Luke, Md.	West Virginia Pulp and Paper Company	45.5	-

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TABLE 2 (Con't.)

Locations and Descriptions of Sampling Stations

Station No.	Stream	Town	Location	River Miles from Source	Drainage Area (sq. miles)
9	North Branch Potomac River	Westernport, Md.	Highway Bridge, Md. Rt. 36 Confluence, Georges Creek	46.9	407
10	Georges Creek	Westernport, Md.	Highway Bridge, Md. Rt. 135	Near Mouth	-
10A	Georges Creek	Barton, Md.	Highway Bridge, Md. Rt. 36 Below Barton	-	-
11	New Creek	Keyser, W. Va.	Highway Bridge, W. Va. Rt. 46	Near Mouth	46
12	North Branch Potomac River	Keyser, W. Va.	Highway Bridge, US. Rt. 220	52.3	498
-	North Branch Potomac River	Keyser, W. Va.	Confluence, New Creek	52.7	545
13	North Branch Potomac River	-	Twenty-first Lane Railroad Bridge	54.1	550
14	North Branch Potomac River	Pinto, Md.	Highway Bridge	67.0	596
-	North Branch Potomac River	Amcelle, Md.	Celanese Corporation Plant	71.9	-
16	North Branch Potomac River	Fairgo, Md.	Cumberland Fairground Beyond far Paddock	73.2	613
17	Wills Creek	Cumberland, Md.	Highway Bridge, US. Rt. 220	-	247
18	North Branch Potomac River	Cumberland, Md.	Highway Bridge, W. Va., Rt. 28	77.4	621

TABLE 2 (Con't.)

Locations and Descriptions of Sampling Stations

Station No.	Stream	Town	Location	River Miles from Source	Drainage Area (sq. miles)
-	North Branch Potomac River	Cumberland, Md.	Confluence, Wills Creek	77.5	868
19	North Branch Potomac River	Cumberland, Md.	Wiley Ford Bridge, W. Va. Rt. 28E	79.6	875
-	North Branch Potomac River	Cumberland, Md.	Cumberland Sewage Outfall	80.9	-
20	Evitts Creek	-	Highway Bridge, Md. Rt. 51	-	-
-	North Branch Potomac River	-	Confluence, Evitts Creek	81.6	-
21	North Branch Potomac River	-	Railroad Bridge, Off W. Va. Rt. 28E near Airport	83.7	980
22	North Branch Potomac River	Oldtown, Md.	Toll Highway Bridge	96.7	1314
-	North Branch Potomac River	-	Confluence, South Branch	98.9	-
23	Potomac River	Paw Paw, W. Va.	Highway Bridge, Md. Rt. 51	107.5	3109

The Cumberland sewage outfall was sampled twice for 24-hour composites; samples were taken every hour and the volume of each sample was made proportional to the flow at that time. The Sargent sampler was not used in this procedure, since a dissolved oxygen determination was not required.

An eight-hour composite was taken at Station 1 while the coal washery was operating. Flow was constant and a uniform sample was taken every half hour.

Samples were taken at Stations 14 and 16 every four hours for a 24-hour period and analyzed separately. This was done because fluctuations in flow and waste load were expected during the sampling period.

During the course of the survey about 2,500 tests were run on 191 samples. The daily sampling routes were each about 190 miles long; the samples arrived at the laboratory less than five hours after the first one had been taken, and all the analyses were started within the next few hours.

Laboratory Determinations: Their Significance

All the determinations except temperature were done in a mobile laboratory of the Public Health Service, parked at the Allegany County Garage in Cumberland. These analyses measured dissolved oxygen (D.O.), biochemical oxygen demand (B.O.D.), chemical oxygen demand (C.O.D.), solids (total, settleable, suspended), color, pH, alkalinity or acidity, dissolved iron (ferrous and ferric), dissolved manganese, tannin and lignin, and sulfates. All tests followed the procedures outlined in

Standard Methods for the Analysis of Water, Sewage, and Industrial Wastes, 10th Edition, except the iron determination, for which the dipyridyl method described in the Ninth Edition of Standard Methods was used.

The significance of each test in evaluating the sanitary quality of a stream is discussed below.

Temperature - The temperature of water controls the oxygen solubility and thus the saturation level of dissolved oxygen in the stream. Since the amount of dissolved oxygen present affects the rate at which a stream assimilates organic wastes, the water temperature is an important criterion in evaluating the sanitary quality of a stream.

pH - pH is defined as the negative logarithm of the hydrogen ion concentration. The pH value indicates the relative acidity or alkalinity of a water, with the neutral point at pH 7.0. Values lower than 7.0 indicate the presence of acid salts and, from pH 7.0 to 14.0, the presence of alkalies or alkaline earth salts is indicated.

Dissolved Oxygen (D.O.) - Normally the amount of oxygen dissolved in water of a stream is limited by the saturation value (9.17 p.p.m. at 20°C) which is a function of water temperature, but in some cases, as result of the photosynthetic action of some water plants, this value may be exceeded, causing "supersaturation." The saturation value decreases with higher temperatures. To support fish and aquatic life and for natural aerobic purification of stream waters, dissolved oxygen must be present. The minimum quantity permissible is dependent on the quality of the water desired and stream flows. Dissolved oxygen must be present to prevent nuisance conditions associated with putrefactive decomposition of waste materials in a stream. Dissolved oxygen values below the saturation level are an indication of the presence of organic pollution which is utilizing oxygen from the stream water. A measure of the effect of pollution of a particular area is given by the deficiency in the dissolved oxygen content below saturation. The quantity of dissolved oxygen in a river of satisfactory sanitary quality is normally considered to be in the range of 5.0 p.p.m.

Biochemical Oxygen Demand (B.O.D.) - The biochemical oxygen demand (frequently referred to as B.O.D.) of sewage, sewage effluents, polluted waters, or industrial wastes is the oxygen (in parts per million) required during stabilization of the decomposable organic matter by aerobic bacterial action. Complete stabilization requires more than 100 days at 20°C, but such long periods of incubation are impracticable in any but research investigations. Consequently a much shorter period of incubation is used. Incubation for 5 days at 20°C is recommended as the standard procedure and this recommendation was followed during the field study. Conversion of the data from one incubation period to another, or from one temperature to another, may be approximated.*

As the amount of dissolved oxygen present decreases with rising temperatures, and at the same time the rate of biochemical oxidation increases as the temperature rises, critical stream conditions usually result during warm months, particularly since these high temperatures are often associated with low stream flows.

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* All B.O.D. data included in this report are based on 5-Day, 20°C. B.O.D. unless otherwise noted.

Coliform Group Organisms - This determination is a sensitive indicator of sewage pollution, since it shows the approximate density of organisms that are normally found only in very small numbers in unpolluted streams. Coliform bacteria are normally present in the intestines of warm-blooded animals and are discharged in vast numbers in human feces, which constitute the main source of these bacteria in sewage. The coliform density is usually measured as "most probable number" (M.P.N.) of organisms per 100 milliliters of sample. This method of reporting the results of examinations is commonly known as the "M.P.N. Index."

Chemical Oxygen Demand (C.O.D.) - This test, otherwise known as Oxygen Consumed or O.C., is an index of pollution supplementary to the B.O.D. test. It measures the total amount of chemical oxygen a waste can consume as determined by oxidation with strong oxidizing agents. The test does not differentiate between biologically stable and unstable organic matter.

Solids (or Residue) - The solids content of a sample is found by evaporating the sample to dryness and weighing the residue. The total solids are found by drying an unfiltered aliquot at 103-105°C. The result indicates the total solids present, both organic and inorganic. Ignition of this residue at 500-600°C. will remove most of the organic material and water of crystallization, leaving the fixed solids as an indication of the amount of inorganic material present. During the ignition process some of the inorganic material undergoes chemical transformation, however, so that the solids tests cannot be regarded as an absolute determination of the relative amounts of organic and inorganic material present. Filtration of the sample, followed by drying and igniting the residue on the filter, gives the corresponding information on suspended solids. Settleable solids, a part of the suspended solids, are found by allowing a sample to settle for a standard period and then measuring the amount of material settled out. This test shows the amount of material that can be expected to settle out in a short reach of a slowly flowing stream; the remainder of the suspended solids indicates the amount of material which may be swept downstream for a relatively long distance under the same flow conditions, to be eventually deposited or dissolved depending on the biology and chemistry of the stream. In a swiftly flowing stream, all the suspended solids may be swept far downstream from the source of pollution before being deposited.

Color and Tannins and Lignins - The color of natural waters is due to dissolved or colloidal substances of vegetable origin extracted from leaves, peaty matter and other similar material. It consists of tannins, glucosides, and their derivatives as well as iron and other substances. These substances have detrimental effects on water distribution systems and should be removed before the water is used for municipal supplies. This removal usually requires difficult and costly treatment. Tannins and Lignins (measured here as tannins) are a part of the coloring material; they result from the partial decomposition of cellulosic material. The color these substances impart is quite intense and persists for many miles in a stream. If a large proportion of the tannins and lignins in a watercourse can be traced to one source, the persistence downstream of the waste containing them can be measured by this test. Both of these determinations are made by colorimetric comparison of the sample with standard solutions.

Alkalinity and Acidity - The alkalinity of water, which may be defined as its capacity for neutralizing acid, is usually due to the presence of bicarbonate and carbonate ions. In some waters hydroxide, borate, silicate, or phosphate ions may also contribute to it. Alkalinity is determined by titration with sulfuric acid to an end point of $pH = 4.0$. In this study all titrations of alkalinity and acidity were performed electrometrically.

The acidity of water may be defined as the capacity for neutralizing base. Acidity is normally associated with the presence of carbon dioxide, mineral and organic acids, and salts of strong acids and weak bases. Mineral Acidity is determined by titration with base to an end point of $pH = 4.5$, and total acidity by titration to an end point of $pH = 8.3$. Acidity and alkalinity are reported as p.p.m. $CaCO_3$.

Iron and Manganese - These metals, when present in a water supply, can be precipitated in distribution systems causing incrustation of pipes and discoloration of the water. Some iron and manganese are present in most natural waters and are usually present in large quantity in acid mine water. They are determined colorimetrically.

Sulfates - Sulfates are a common decomposition product of organic matter. They are also a product of reactions involving acid mine drainage. In water supplies sulfates have certain undesirable physiological effects in man. They are determined gravimetrically as barium sulfate.

PRESENTATION OF DATA

Laboratory Results of the 1956 Field Survey

The laboratory data on individual samples obtained during this survey are presented in Table A-1 of the Appendix.

The average of results at each sampling station are presented in Table 3. Where the average presented is based on less than the total number of samples taken at a given station, the number of determinations used to obtain the average is indicated in parentheses after the average.

Averaged results for stations on streams subject to acid mine drainage are presented in Table 4. Some data from streams not subject to this waste are presented for comparison.

Stream-Flow Data

Discharge measurements for the period of the field survey are presented in Table A-2. The data are daily mean discharges as provided by the U. S. Geological Survey.

In Table A-3 are presented hourly discharges at Stations 6, 7, 9, and 14 for the periods when composite samples were being taken.

Data from Other Sources

Data of the West Virginia Pulp and Paper Company for the period 1949-1955 on pH and acidity in the North Branch above the paper mill are presented in Table A-4.

The approximate locations of the proposed damsites are presented in Figures 1 and 4. On the Savage River, the proposed site is immediately above the existing reservoir; on the Stony River, the proposed

TABLE 3

Averages of Results
at Each Sampling Station

Station	Temp. (°C)	Discharge (cfs)	D.O. (ppm)	B.O.D. (ppm)	B.O.D. #/Day	C.O.D. (ppm)	C.O.D. #/Day)	Solids (ppm)								Color (rcm)	pH	Alkalinity,ppm (Acidity,ppm)		Dissolved Fe(ppm)	Dissolved Fe^{++}(ppm)	Dissolved Mn(ppm)	Tannin (ppm)	Sulfate (ppm)
								Total (w/o Set.S.)	Settleable	Total Fixed	Total Volatile	Total Suspended	Suspended Fixed	Suspended Volatile	Dissolved			Phen. (M.O.)	Total (Total)					
1	9.4	4.8	7.10	2.9		-		1830(6)	5300	415(6)	1415(6)	1610(4)	774(4)	836(4)	389(4)	45	3.6	(40.9)	(128)	-	-	-	-	-
2	9.9	33	9.50	0.64		-		420(5)	170(6)	230(5)	188(5)	6.9(3)	2(3)	4.9(3)	360(3)	15	3.5	(47.0)	(100.2)	-	-	-	-	-
3	10.0	39	9.06	0.44	80.3	-		388(5)	180(6)	204(5)	184(5)	21.1(3)	5.0(3)	16.1(3)	312(3)	19	3.5	(40.5)	(93.0)	-	-	-	-	-
4	10.6	34	9.48	0.81		-		152(5)	0(5)	96(5)	56(5)	16.3(4)	7.0(4)	9.3(4)	119(4)	42	6.5	-	(1.6)8.1	0.81(5)	0.08(3)	0.16(4)	-	1.2(3)
5	11.1	155	9.50	0.78	637	-		176(5)	67(6)	120(5)	56(5)	5.0(3)	1.5(3)	3.5(3)	128(3)	7	4.4	(2.2)	(16.5)5.4	0.72	0.09(3)	0.50	-	4.3(2)
6	14.3	164	9.55	1.2	979	-		224(5)	0(5)	172(5)	52(5)	8.5(4)	4.8(4)	3.7(4)	195(4)	6	4.2	(7.1)	(38.8)1.0	1.02	0.19	0.73(3)	-	-
6 - 24	-	245	-	0.64	964	4.04		133	0	73	60	11.8	4.0	7.8	121	6	4.2	(4.0)	(16.0)2.1	0.42	-	0.42	0.22	6.1
6 - 0	12.5	273	9.35	0.67	915	11.01	20800	185(4)	0(4)	105(4)	80(4)	14.2(4)	5.5(4)	8.7(4)	171(4)	3	4.3	(2.6)	(23.1)	1.09(2)	-	0.54(2)	0.40	6.5(6)
7	13.1	104	9.90	0.85	414	-		120(5)	0(5)	72(5)	48(5)	6.9(4)	2.7(4)	4.2(4)	98(4)	14	7.4	-	18.0	0.23(6)	0.02(3)	0.19	-	-
7 - 24	-	114	-	0.51	317	5.35		106	0	53	53	7.5	0.4	7.1	98.5	13	7.1	-	19.1	0.12	0.05	0.28	-	1.32
7 - 0	12	117	9.82	0.82	519	5.95	3760	100(4)	0(4)	65(4)	35(4)	13.8(4)	6.1(4)	7.7(4)	86(4)	12	7.3	-	18.7	-	-	-	0.34	1.05(4)
8	11	11.2	10.10	0.60	38.9	-		92	0	48	44	4.8	2.1	2.7	87	14	6.9	-	19.0	0.09	0.04	0.10	-	-
9	16	372	6.86	23.0	35800	98.2	170000	335	1100	155	180	74.7	27.5	47.2	260	100	7.3	9.3	46.3	0.95(1)	-	0.46(1)	5.6	6.3
9 - 24	-	360	-	25.7	49400	85.8	166000	277	0	160	117	65.8	24.6	41.2	211	100	7.0	-	33.3	0.53	-	0.43	4.7	5.7
10	11	72	9.77	2.5	292	17.0	6370	723	50	510	213	57.1(6)	40.8(6)	16.3(6)	666(6)	6	4.3	(7.3)	(37.0)2.0	-	-	-	0.09	41.4(6)
10A	1	18	9.72	2.1		3.05(3)	570(3)	528(5)	0(5)	356(5)	172(5)	32.6(5)	17.8(5)	14.8(5)	495(5)	7	6.9	-	19.6	0.37	-	-	-	29.2(5)
11	11	14	9.46	1.6	350	7.27	1580	220(5)	0(5)	100(5)	120(5)	27.3(5)	20.8(5)	6.5(5)	192(5)	12	7.7(5)	-	96.5(6)	-	-	-	-	-
12	14	437	6.25	14.8	34200	74.4	169000	291	800	154	137	55.7(6)	16.3(6)	39.4(6)	244(6)	84	7.4	2.0	36.4	0.78(4)	-	0.49(3)	4.6	-
13	15	483	6.74	13.4	32200	57.7	145000	267(6)	1000(6)	133(6)	133(6)	40.1(5)	13.3(5)	26.8(5)	224(5)	80	7.0	-	29.8(6)	-	-	-	-	-
14	16	400	6.19	7.3	16200	43.4	99000	218	0	144	74	36.7(8)	16.2(8)	20.5(8)	181(8)	81	7.1	-	37.3	1.11(6)	0.28(1)	0.57(6)	3.2(7)	-
16	17	446	6.10	9.7	25300	46.7	132000	272	0	220	52	46.2(4)	25.5(4)	20.7(4)	219(4)	69	6.7	-	37.0	-	-	-	-	-
17	14	85	9.91	5.3	2220	17.6	7840	312	0	256	56	83.9(4)	73.1(4)	10.9(4)	211(4)	17	7.2(4)	-	42.6(4)	0.17(2)	0.035(2)	0.52(2)	0.23(3)	-
1	17	476	3.28	7.6	20900	37.6	106000	235(4)	0(4)	190(4)	45(4)	22.6(3)	9.6(3)	13.0(3)	197(3)	69	6.9	-	46.4(4)	1.44(3)	0.24(2)	0.77(3)	2.91	-
19	16	568	6.86	4.6	14500	35.0	98500	299	0	168	68	40.4(4)	31.1(4)	9.3(4)	185(4)	67	7.0	-	48.0(4)	-	-	-	-	-
20	14	14	11.65	1.15	79	10.34	740	180(4)	0(4)	140(4)	40(4)	35.8(4)	29.8(4)	6.6(4)	144(4)	20	7.8(4)	-	105.5(4)	-	-	-	-	-
21	16	599	5.40	4.3	13700	33.2	102000	272	0	228	44	34.6(4)	24.5(4)	10.0(4)	195(4)	74	7.1	-	51.4(4)	1.24(3)	0.28(2)	0.70	2.6	-
22	16	728	6.48	2.5	10700	24.3	94300	260	0	196	64	24.2(4)	17.0(4)	7.2(4)	226(4)	51	7.2	-	53.0	0.93(3)	0.17(2)	0.39(3)	1.6	-
23	16	1030	7.93	1.4	8550	15.4	85300	200	0	145	55	18.8	14.2	4.7	181	40	7.3	-	55.4	0.62	0.08(1)	0.46	1.04	-

TABLE 4

Summary of Data from Regular Sampling Station
in Areas Subject to Acid Mine Drainage

Station	1	2	3	4	5	6	7	8	10	10A	17
Average:											
Temp. (°C.)	9	10	10	11	11	13	13	11	11	11	14
Discharge (cfs)	4.8	34	39	34	155	164	104	11	22	18	85
D.O. (ppm)	7.10	9.50	9.06	9.48	9.50	9.55	9.90	10.10	9.77	9.72	9.91
B.O.D. (ppm)	2.1	0.5	0.5	0.8	0.8	1.2	0.9	0.6	2.5	2.1	5.3
Color (ppm)	45	15	19	42	7	6	14	14	6	7	17
pH	3.6	3.5	3.5	6.5	4.4	4.2	7.4	6.9	4.3	6.9	7.2
Mineral Acidity (ppm)	40.9	47.0	40.5	0	2.2	7.1	0	0	7.3	0	0
Total Acidity (ppm)	128	100	93	1.6	16.5	38.8	-	-	37.0	-	-
Total Alkalinity (ppm)	-	-	-	8.1	5.4	1.0	18.0	19.1	2.0	19.6	42.6
Dissolved Iron (ppm)	-	-	-	0.8	0.72	1.0	0.23	0.09	-	-	.17
Dissolved Manganese (ppm)	-	-	-	0.16	0.50	0.73	0.19	0.10	-	-	.52
Solids:											
*Total (ppm)	1830	420	388	152	176	224	120	92	723	528	312
Settleable (ppm)	5.1	0.2	0.2	0	0.1	0	0	0	0	0	0
Total Fixed (ppm)	415	230	204	96	120	172	72	48	510	356	256
**Total Suspended (ppm)	1610	6.9	21	16	5	8.5	6.9	4.8	57	33	84

* Average based on seven determinations
** Average based on three to five determinations

site is a short distance downstream of the U. S. Route 50 highway bridge; on the North Branch, a site near and upstream of Bloomington is proposed. The regulated flows to be developed independently at each site are:

Savage River - - - - - - - - - - - 45 cfs
Stony River - - - - - - - - - - - 60 cfs
North Branch - - - - - - - - - - - 170-207 cfs

Water Quality Objectives for the North Branch

The Maryland Water Pollution Control Commission has established standards for industrial waste discharges into streams in Maryland. The text of the controlling regulation is presented here.

> "No industrial wastes other than acid-mine drainage shall be placed or permitted to be placed or discharged or permitted to flow into any of the waters of the State in any manner by any person unless the industrial wastes after treatment or untreated shall meet with the nine industrial waste requirements established by the Water Pollution Control Commission before being discharged into any waters of the State. These nine industrial waste requirements are as follows:
>
> 1. Solids:
>
>   A. Solids in the effluent - Must not exceed 1/32 inch particle size. Grinding, maceration or any other waste treatment or handling operation intended to reduce the size of the oversize solids in the effluent to less than 1/32 inch, will not be permitted or approved.
>
>   B. Total suspended solids - Must not exceed 1500 ppm.
>
>   C. Dissolved solids - Must not exceed 1500 ppm.
>
>   D. Total solids - Must not exceed 1900 ppm.
>
> 2. Turbidity - Must transmit 10% of light through 12 inches of sample in a 3 inch column or not to exceed 300 ppm., as determined by the Jackson Candle turbidimeter.

3. Biochemical Oxygen Demand:

   A. The Biochemical Oxygen Demand - The 5-day 20°C. Biochemical Oxygen Demand in the effluent must not exceed 100 ppm.

   or

   B. The Dissolved Oxygen in the waste receiving waters must not be depleted beyond 50% of normal saturation.

4. Toxicity or toxic compounds - Eliminate, or reduce to limits of tolerance, substances toxic to humans, livestock, fish, aquatic and wildlife.

5. Color - Color intensity regardless of light frequency must not exceed 400 ppm on the chloroplatinate scale.

6. pH - Must not range below 5.5 or above 8.5.

7. Temperature - Must be below 100 degrees F in the stream within 50 feet from waste outlet.

8. Oils and grease in the effluent must not exceed 30 ppm.

9. Taste and odor - Effluent must not exceed threshold odor number of 1000. Mixture of the waste and receiving waters shall have a threshold odor number not in excess of 80.

All analyses to be conducted in accordance with the American Public Health Association Standard Methods.

These nine industrial waste requirements are generally applicable values but are not absolutely fixed values. They can be made more stringent if a survey of the waste receiving waters indicates they are still polluted or are continuing to be degraded, or in any instance where the Water Pollution Control Commission after due study and deliberation deems that more stringent requirements are necessary. They can be made more liberal only by formal action of the Commission on the basis of satisfactory evidence and proof that waste-receiving waters are sufficient in quantity and quality to not be affected adversely by a particular industrial waste effluent having values in excess of those stated above.

Any industrial wastes, after treatment or untreated, which do not meet with the above requirements shall be deemed and considered in violation of this regulation based on Laws of

Maryland, Chapter 697 of the Acts of the General Assembly of the State of Maryland of 1947, and shall be subject to penalties imposed thereby. Each day upon which a violation occurs under this regulation shall be deemed a separate and additional violation.

This revised regulation approved December 12, 1949 supersedes the previous Regulation IV which was effective August 1, 1948.

Revised and approved by the Water Pollution Control Commission, September 29, 1953."

STATE OF MARYLAND
WATER POLLUTION CONTROL COMMISSION

L. B. Phillips, Jr., Chairman
Paul W. McKee, Director

The Maryland State Department of Health can require reductions of water pollution wherever a public health menace exists. No over-all criteria for pollutional limits are established, and each case is considered separately.

The Interstate Commission on the Potomac River Basin has prepared and adopted water quality criteria to permit classification of all the streams in the Potomac River Basin. The criteria for classifying streams are presented in Table 5. The Commission has also compiled water quality objectives for the individual streams of the Basin.

The standards of the Maryland Water Pollution Control Commission and those of the Interstate Commission are applied to two different materials. The standards of the Maryland agency apply to the industrial waste effluent itself except for three criteria, one which relates to the D.O. in the receiving stream (Section 3.B.), one which relates to the temperature of the receiving stream (Section 7.), and one which relates to odor (Section 9.). For example, the regulation states that

TABLE 5

INTERSTATE COMMISSION ON THE POTOMAC RIVER BASIN

Minimum Water Quality Criteria for Streams in the Potomac River Basin

Approved 8 August 1946

	CLASS A Drinking Water (No treatment except cl.)	CLASS B Bathing, Fish Life	CLASS C Domestic Water Supplies (Before complete treatment) Industrial Process Water	CLASS D General Sanitary Condition - to prevent nuisance
Coliform Bacteria MPN per 100 ml.	0 - 50	Mo. av. 50 - 500 Max. not over 1000	Mo. av. 500 - 5000	----------
Color, ppm	0 - 10	20 (desirable)	Amt. of color and turbidity allowed which can be removed by standard equipment and practices	----------
Turbidity, ppm	0 - 10	40 (desirable)	----------	----------
pH	6.0 - 8.0	6.0 - 8.5	6.0 - 8.5	6.0 - 8.5
5 Day B.O.D., ppm	------			
Monthly av. ppm	------	1.5	2.0	3.0
Max. observa. ppm	------	3.0	4.0	5.0
Dissolved Oxygen, ppm				
Monthly av. ppm	7.5	6.5	6.5	4.0
Min. observa. ppm	6.5	5.0	5.0	Min. daily av. 3.0 Absolute min. 2.0
Other Conditions	No toxic substances oil, tars, or free acid at any time. No floating solids or debris, except from natural sources. No taste - or odor - producing substances. No sludge deposits.	Same as A	Same as A	No toxic substances oils, tars, or free acid at any time. No floating solids or debris except from natural sources. Slight localized sludge deposits, if unpreventable, allowed. No offensive odors.

NOTE: These criteria are to be used only in conjunction with a sanitary survey as a guide in determining the minimum water quality for the various classes of water use listed. It is intended that these criteria should apply to conditions which are expected to prevail for the major part of the time.

the color in the effluent must not exceed 400 ppm; it places no restrictions on what the color may or may not be in the receiving stream. All of the criteria established by the Interstate Commission apply to conditions in the receiving stream, regardless of what the waste effluent contains.

The standards of the Interstate Commission for Class D streams appear to be an adequate objective for pollution abatement measures in the North Branch between Luke and Oldtown. In developing benefits, it was assumed that the Class D stream criteria were the water quality objectives to be achieved by a combination of dilution and additional waste treatment.

DISCUSSION OF 1956 FIELD SURVEY DATA

Water Supplies

Municipal - Except for the town of Luke municipal and private water supplies come either from wells or from small streams. Luke is supplied with North Branch water treated by the West Virginia Pulp and Paper Company. The Piedmont-Westernport area obtains much of its water from the Savage River Dam; Keyser has a municipal dam and reservoir on Limestone Run. Frostburg likewise has its own surface water supply; the other communities either rely on private wells or are supplied by the City of Cumberland.

The City of Cumberland has two municipal reservoirs on Evitts Creek which have a combined storage capacity of 3.63 billion gallons of water. The present daily consumption of water from these sources is 12.5 million gallons and could increase to 18 million gallons. The City has the watershed rights available to provide considerably more water if the need arises. City officials feel that the volume already available is adequate for both present and anticipated needs for the near future and that the cost of treatment is very low. However, for long range planning, consideration should be given to use of waters from existing Savage River Reservoir.

Industrial - Cumberland city water is used by all the large industries in the vicinity. Table 6 presents the major industrial consumers of Cumberland water and their average daily consumptions.

The Pittsburgh Plate Glass Company is also using some Cumberland water at present; however, when their plant facilities are complete, all

TABLE 6

Consumption of Cumberland City Water by Industries

Company	Daily Consumption (gallons)
Celanese Corporation of America	2,000,000
Kelly-Springfield Tire Company	920,000
B. & O. Railroad Company	480,000
Cumberland Brewery	200,000
Queen City Brewery	160,000
Potomac Edison Power Company	70,000

the industrial process water and cooling water will be drawn from the North Branch below Cumberland. Sanitary water will still come from the Cumberland supply.

The North Branch supplies water for several industries:

The West Virginia Pulp and Paper Company uses about 40 million gallons daily. Part of this water is treated in a filtration and chemical-treatment plant and is then used for both process and sanitary purposes.

The Celanese Corporation plant now uses about 25 million gallons daily of North Branch water, 40 mgd when it is operating at capacity. Treatment is limited to sedimentation, since this water is used primarily for cooling purposes. Process water is treated Cumberland city water.

The Kelly-Springfield Tire Company uses 10-15 million gallons daily of North Branch water without treatment for cooling purposes.

The Potomac Edison Company uses about 40.5 million gallons daily of North Branch water for cooling purposes.

The Pittsburgh Plate Glass Company will use about 2 million gallons daily from the North Branch, treating it separately for each individual process. All of these companies would welcome improvement of the water quality in the North Branch. At Luke the major deficiency is the acid nature of the water, and below Luke there is some trouble with slime in piping systems.

Additional flow in the North Branch would improve the quality of the water used by these plants and would decrease the difficulties of using North Branch water.

Water Pollution

The North Branch of the Potomac receives pollution of three different types: acid mine drainage, industrial wastes, and municipal sewage.

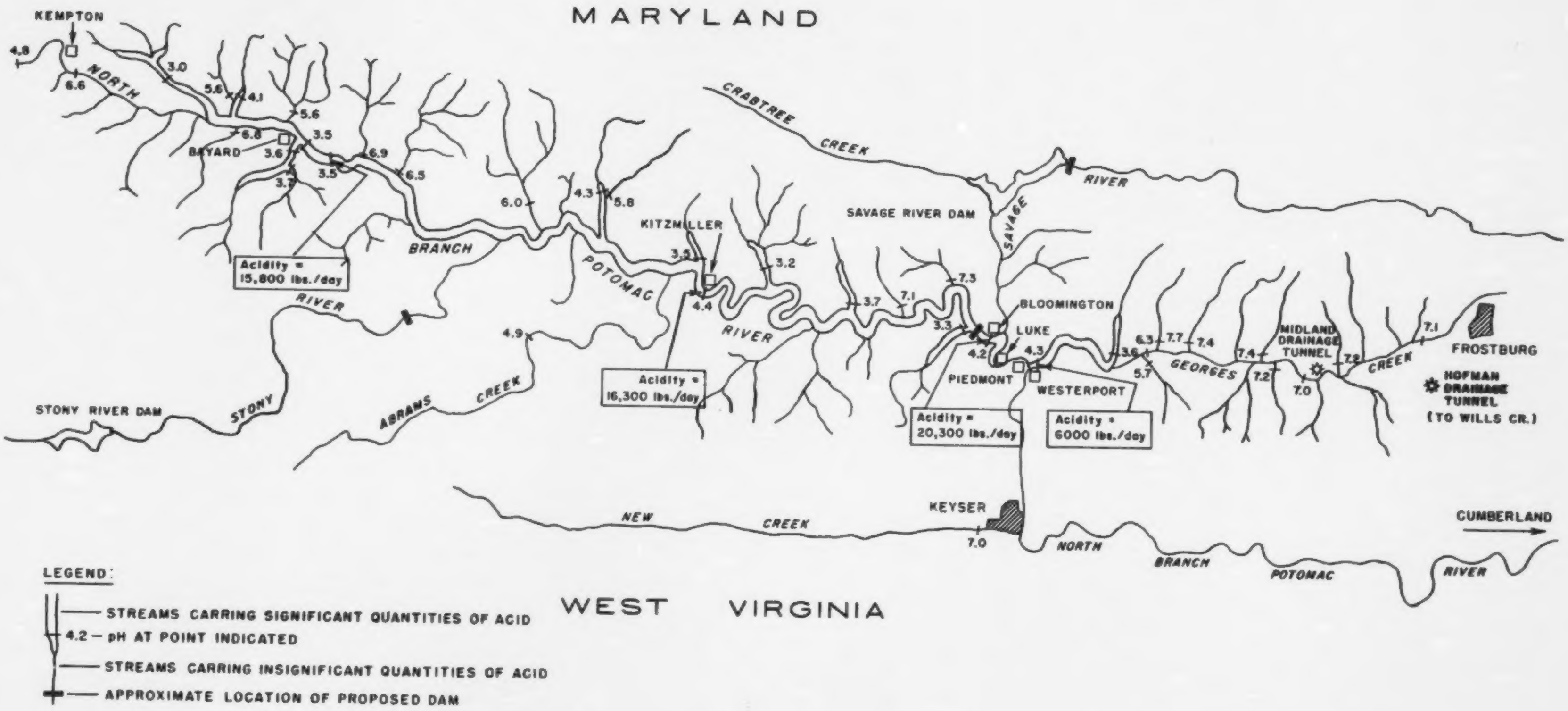
Acid Mine Drainage

Coal production in the past has been widespread on the North Branch watershed. Now, as a result, the region is pocketed with abandoned mines no longer operated because of worked-out seams or lack of demand for the coal. These mines receive water seepage from the surrounding strata; the water, interacting with air and minerals present in the mines, forms sulfuric acid which eventually finds its way out of the mines and into the surface waters. Streams containing much acid mine drainage are usually sterile, as fish, algae, and other aquatic life cannot live in a strongly acid medium. The bordering vegetation watered by these streams is also adversely affected by acid wastes, and unprotected concrete and iron structures are eaten away if exposed to them for long periods.

The bed of a stream carrying acid mine waste has a characteristic reddish color, caused by deposited iron salts, and a lack of vegetation, caused by the sterilizing effect of the acid. In the laboratory an acid stream is recognized by its low pH (about four as opposed to about seven for a normal stream), the presence of high acidity and iron, and generally high dissolved solids.

Many of the streams discharging into the North Branch carry acid mine waste; above Luke the river is polluted by this material for most of its length. A reconnaissance of tributary streams was made with a representative of the Maryland Bureau of Mines, and determinations of pH (a measure of acidity) were made at each stream it was possible to reach. Figure 4 shows which streams are contributing significant amounts of acid waste to the river, their pH values, and some average acid loads, i.e., the average amounts of acid carried in pounds per day; similar measurements are included for the North Branch at several points.

The concentration of acid waste in streams is naturally determined by the number and/or size of the abandoned mines in each stream's drainage area. Kempton Mine, the largest in the river basin, discharges its waste through Laurel Run which enters the Potomac about seven miles from its source. The most extensively mined section in the region is the Big Vein area in Allegany County, Maryland, located in the Georges Creek basin. Three drainage tunnels connect most of these mines, carrying their wastes directly to streams and preventing in large


MARYLAND
WEST VIRGINIA
KEMPTON
4.8
6.6
NORTH
3.0
5.6
4.1
5.6
6.8
BAYARD
3.6
3.5
3.7
3.5
6.9
6.5
Acidity = 15,800 lbs./day
BRANCH
RIVER
STONY RIVER DAM
STONY
6.0
4.3
5.8
KITZMILLER
3.5
4.4
3.2
POTOMAC
RIVER
Acidity = 16,300 lbs./day
4.9
ABRAMS CREEK
CRABTREE CREEK
SAVAGE RIVER DAM
SAVAGE
RIVER
3.7
7.1
7.3
3.3
4.2
BLOOMINGTON
LUKE
4.3
PIEDMONT
WESTERPORT
Acidity = 20,300 lbs./day
Acidity = 6000 lbs./day
3.6
6.3
7.7
7.4
5.7
GEORGES
7.4
7.2
MIDLAND DRAINAGE TUNNEL
7.0
7.2
CREEK
7.1
FROSTBURG
HOFMAN DRAINAGE TUNNEL (TO WILLS CR.)
KEYSER
7.0
NEW CREEK
NORTH BRANCH POTOMAC RIVER
CUMBERLAND
LEGEND:
STREAMS CARRING SIGNIFICANT QUANTITIES OF ACID
4.2 – pH AT POINT INDICATED
STREAMS CARRING INSIGNIFICANT QUANTITIES OF ACID
APPROXIMATE LOCATION OF PROPOSED DAM

EXTENT OF POLLUTION FROM ACID MINE DRAINAGE IN THE BASIN OF THE NORTH BRANCH POTOMAC RIVER

FIGURE 4

measure the contamination of the ground water in this area. Only one of these ducts, the Midland Drainage Tunnel, empties within the basin, discharging directly into Georges Creek which enters the river at Westernport. The other two are the Hoffman Drainage Tunnel, discharging to Braddock Run, and the Allegany Water Ditch, discharging to Jennings Run. Braddock Run and Jennings Run both join Wills Creek, which empties into the North Branch at Cumberland.

North Branch Potomac River

The major acid-mine-drainage load in the North Branch at this time occurs in the reach above Luke. This reach receives waste from mines throughout its entire length, beginning at Kempton, a few miles from its source, and continuing until a few miles above its confluence with the Savage River. The tributaries to the main stem were inspected, and those found to be carrying large quantities of acid mine drainage are identified on Figure 4.

The North Branch is decidedly acid from above Bayard to Luke. The amount of acid carried varies from point to point along the river. There are probably several reasons for this: precipitation of some iron salts, neutralization of acid by the natural alkalinity of inflowing streams, and dilution with purer waters.

Stony River

The Stony River contained no measurable mineral acidity, and, as far as problems with acid mine drainage are concerned, this river would provide waters quite suitable for all recreational and water supply uses. Iron and manganese are present in this stream but not in quantities sufficient to cause problems in a reservoir; to make this water comply with Public Health Service drinking water standards for iron and manganese, some must be removed.

Savage River

The Savage River above the existing dam is an extremely clean stream, showing no trace of acid mine drainage and very small amounts of iron and manganese.

Georges Creek

Georges Creek receives drainage from mines along its basin and from the Midland Drainage Tunnel. The Midland Drainage Tunnel, upstream from Barton, apparently carried little acid waste during this survey, since the pH of Georges Creek did not change at the tunnel outlet. This does not mean that the Midland Drainage Tunnel no longer carries acid mine waste, because acid flow from mines can fluctuate widely according to the rainfall, runoff, and seepage.

Two sampling stations were established on Georges Creek, one at Westernport and one above Barton. No evidence of acid mine waste was found in the stream above Barton, but an average load of 6,000 lbs/day was measured at Westernport. These results indicate that, at present, most of the mine drainage enters the stream below Barton; a large amount was traced to Mill Run, and the bulk of the remainder is direct drainage from mines along the creek banks. This waste adds to the local pollution problem in Georges Creek, but it does not measurably affect the much greater pollution load already in the North Branch.

Wills Creek

Wills Creek receives, by way of Jennings Run and Braddock Run, respectively, drainage from the Allegany Water Ditch and the Hoffman Drainage Tunnel, which serve many mines on the Georges Creek watershed and in the Frostburg vicinity. Jennings Run and Braddock Run both show visible signs of acid mine drainage, but both have pH values of 5.6; these readings indicate little total acidity and no mineral acidity.

Wills Creek was sampled near its mouth in Cumberland. Data obtained there show no evidence of acid mine drainage; in fact, the total alkalinity of 42.6 and the pH of 7.2 indicate that the stream could neutralize much more acid than it now receives.

Industrial Wastes

Fairfax Coal Washery, Bayard, W. Va.

This company sprays freshly mined coal with water to flush away solid impurities. The washery operates intermittently according to the amount of coal available, usually three to five days per week, seven hours per day. The plant is located in Bayard, W. Va., and discharges its wastes to Buffalo Creek, which enters the North Branch about a mile below the plant. The wastes are primarily large quantities of coal dust and other finely divided solids which discolor Buffalo Creek and the North Branch at all times for several miles. During periods of low-flow these coal fines tend to settle in the numerous pools, and in times of high water this accumulation is resuspended and carried downstream. The North Branch is usually black below Gorman and frequently black as far downriver as Kitzmiller. Occasionally black water is found as far downstream as Luke.

Previous experience* has shown that coal washery wastes alone do not produce a significant increase in B.O.D. The primary contaminants are coal fines which may be carried for miles downstream; they discolor the water and stream bed, ruining the stream for recreational purposes, impairing the quality of sand and gravel deposits, damaging the food supplies of aquatic life, and creating a visual nuisance. The data accumulated on this present survey confirm these findings.

Effluent from the coal washery was sampled on Buffalo Creek about a half mile below the plant. The B.O.D. averaged 2.9 ppm. (Buffalo Creek contains some sewage.) Dissolved oxygen averaged 7.1 ppm. Mineral acidity averaged 41 ppm and total acidity 130 ppm; since the stream contained acid mine waste before it reached the coal washery, it was impossible to estimate how much acidity, if any, was due to the coal washery wastes without data which was unobtainable because of the local terrain.

A composite sample was collected throughout a typical operating day. Solids determinations were run on this sample; the results, along with the solids results from a grab sample taken when the washery was not operating, are presented in Table 7.

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* Report of the United States Public Health Service, Ohio River Pollution Control, Supplement to Part Two, House Document No. 266, 78th Congress, 1st Session, 1943, pp. 1071-81.

TABLE 7

Solids Data on Buffalo Creek at Bayard

	Plant in Operation Eight-hour Composite		Plant Not in Operation Grab Sample	
	ppm	Total Pounds Discharged	ppm	Pounds per Eight-hour Period
Total*	2580	18600	360	3900
Settleable	13500	292000	4600	14900
Total Fixed*	650	4700	120	1300
Total Volatile*	1930	13900	240	2600
Total Suspended*	2445	17600	11	120
Suspended Fixed*	1245	9000	3	32
Suspended* Volatile	1200	8600	8	86
Dissolved	135	1000	349	3800

* Does not include Settleable.

These data give a qualitative indication of the amount of solid material discharged during coal-washery operation. The grab sample also contained some solids from the coal washery's discharge in addition to the acid drainage from mines along Buffalo Creek. The coal washery causes a tremendous increase in total solids, most of which is in settleable and suspended form.

Estimates based on the data given in Tables 4 and 7 indicate that, when flow is low and steady, virtually all of the settleable solids and 50 to 75 per cent of the suspended solids settle out or otherwise disappear in the 2.2 river miles to Sampling Station 3 at Gorman. The rest of the coal washery waste is fairly well dissipated in the next 15 river miles to Sampling Station 5 at Kitzmiller. The North Branch between Bayard and Kitzmiller is a series of still pools alternating with rapids. Spot checks of typical reaches indicate that much of the coal waste is deposited in the pools during periods of low-flow. These pools are probably scoured out when high flows occur, causing the "black water" seen at Kitzmiller and at Luke.

At present there is a possibility that the company's washing contracts will be cancelled, forcing the washery to close. If operations continue, the State of West Virginia has asked the Fairfax Coal Washery to provide some sort of treatment for its wastes. The Company plans to install a settling basin. Such a basin properly designed and operated, would eliminate most of the solids load now entering the North Branch through Buffalo Creek.

West Virginia Pulp and Paper Company, Luke, Md.

The waste loads discharged by the plant during this field survey were measured as the differences between samples taken above and below the plant, rather than from direct sampling of the many effluent streams. Table 8 gives averages of these differences for the three 24-hour-composite samples taken at Stations 6, 7, and 9. The waste load determined in this manner should be less than the actual waste load discharged since some waste reduction can be expected between the plant and the downstream sampling station.

TABLE 8

Measured Waste Loads from the West Virginia Pulp and Paper Company, Luke, Md. (from 24-Hour Composites)

	Pounds per day
B.O.D. (5-day, 20°)	47400
B.O.D. (ultimate)	57800
C.O.D.	156000
Total Solids	252000
Total Fixed Solids	145000
Total Volatile Solids	107000
Suspended Solids	106000
Suspended Fixed Solids	39000
Suspended Volatile Solids	67000
Alkalinity	61800
Tannin & Lignin	8000
Color	PPM 90

This plant imposes on the North Branch the largest waste load from any single source in the basin. Analyses of the three 24-hour composite samples taken about one third mile above the plant and about a mile below the plant show that the waste load discharged in this reach is equivalent in organic pollution load to the sewage from a city of nearly 300,000 people.*

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* Based on 0.17 pounds per capita per day of 5-day, 20° C. B.O.D.

The problem presented by waste from the Luke plant has been studied intensively by the Maryland Water Pollution Control Commission, the Interstate Commission on the Potomac River Basin, and the West Virginia Pulp and Paper Company, which regularly samples the North Branch both above and below Luke. The Public Health Service has reviewed studies by all of these groups in preparing this report.

The existing production facilities at Luke consist of a sulfate pulp mill, a bleach plant, and seven paper machines that produce coated and uncoated papers and boards. Production is normally about 400 tons per day of papers and boards; however, while this survey was in progress, the plant was exceeding its rated capacity. Wastes from such a plant may include partially reduced wood pulp, wood fibers, digester liquors, dyes, coating materials, and small quantities of mercaptans. Loading a stream with these materials creates an extremely unhealthy environment for aquatic life. Characteristic effects of these wastes are the depletion of dissolved oxygen to levels at which fish cannot live, and the deposition of solid material as sludge which covers the stream bed to such an extent that normal aquatic plant life cannot exist.

The waste discharge from the Luke mill was estimated by the plant to be about 40 million gallons of effluent per day for the year 1955. This included 241,100 pounds per day of total solids and 24,200 pounds per day of B.O.D.* The wastes flow through numerous outfalls directly into the North Branch; nine sewers carry about 50 per cent of the flow and about 99 per cent of the waste load. The other outfalls discharge either highly dilute wastes or cooling waters.

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* Data supplied to the Maryland Water Pollution Control Commission by the West Virginia Pulp and Paper Company.

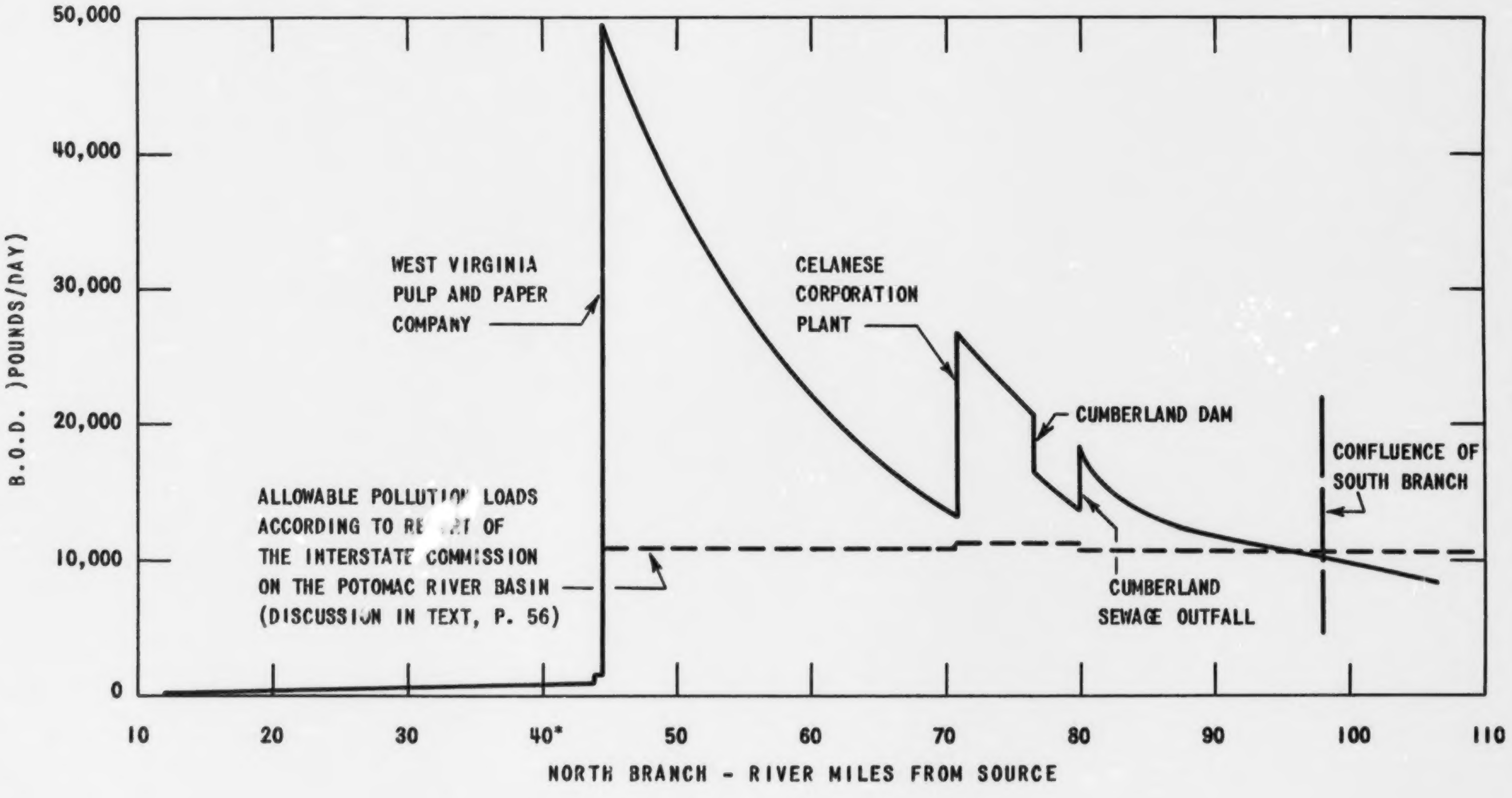
The effects of the paper mill waste on the river are immediately noticeable. The North Branch at Westernport is highly colored, usually a dirty gray or black. Solid material is frequently visible in the water, and the stream bed is covered with gray slime. At Westernport the North Branch has an overpowering stench, and the same smell (probably from mercaptans in the waste) is noticeable below Cumberland at Station 19. Foam builds up on the surface in a pool below the mill outfalls and is carried downstream in slugs; scum similar in appearance and odor to that below the plant accumulates along the banks as far downriver as Oldtown, Md.

The plots in Figure 5 show the B.O.D. in the North Branch. The B.O.D. waste load from the West Virginia Pulp and Paper Company is still obvious at the point where Celanese discharges its waste; farther downstream, a measurable amount of their waste is still entering the Cumberland Pool.

Dissolved oxygen is not depleted as much as the B.O.D. load would ordinarily reduce it. Average D.O.'s at stations on the North Branch are plotted in Figure 6. The minimum oxygen contents in the reach immediately below the paper mill were 2.1 ppm at Station 9 and 2.4 at Station 12; the lowest C.O. in the entire North Branch was 0.6 ppm at Station 18, the pool behind the Cumberland Dam. In general, however, dissolved oxygen only depleted to about two-thirds of that at Stations 6 and 7, indicating that the stream has a very high reaeration rate.

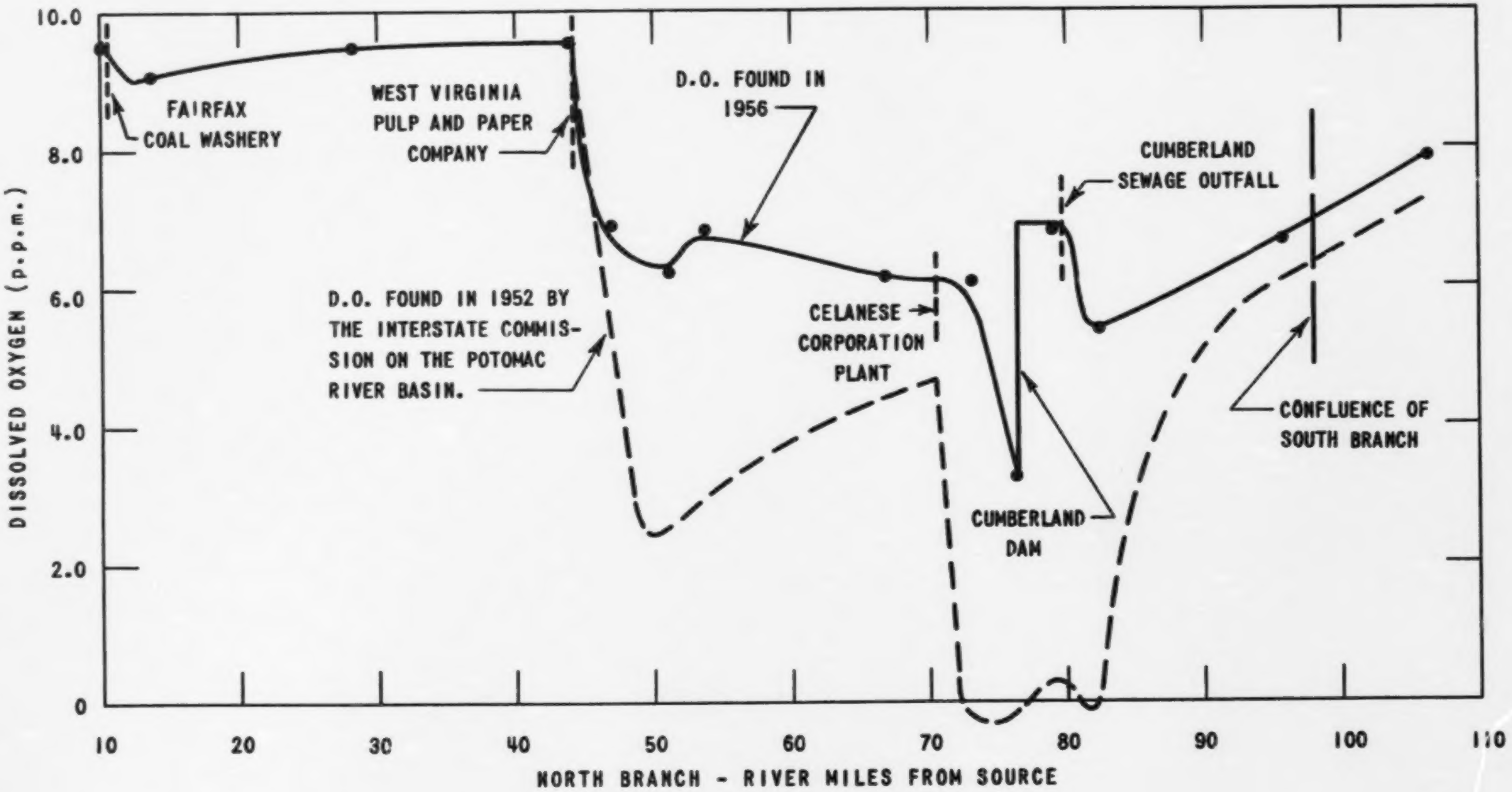
Such oxygen recovery probably results from one major characteristic of the North Branch in the reach from Luke to Cumberland. The stream flows through a series of pools and riffles, so that much of the D.O. lost in a quiet pool is recovered as the water cascades into the next pool. This concept is borne out by actual measurements: the D.O. in one short stretch of rapids between Westernport and Keyser increased 3 ppm; the D.O. in water spilling over the dam at Cumberland rose from 1.5 ppm to 5.5 ppm, an increase of 4 ppm in a fall of 10 feet. The reaeration capacity of the river will change radically as the river stage changes, lengthening and shortening the stretches of rapids between pools, causing wide variations in D.O. recovery throughout the length of the river, and, consequently, wide variations in D.O. at any point on the river.

Chemical oxygen demand (C.O.D.) is a measure of the total oxygen-consuming power of a waste. It cannot be directly correlated with B.O.D., although a correlation for a specific waste may be developed. The C.O.D. is used as additional index of organic pollution, a more comprehensive index than B.O.D. Figure 7 graphs the average C.O.D. along the North Branch. It shows a curve similar to that for B.O.D. in Figure 5, indicating that oxygen-consuming materials are stabilized or deposited on the stream bed; however, the C.O.D. is not reduced in the stream as rapidly as is the B.O.D. While the river between Luke and Cresaptown removes about 75 per cent of the B.O.D., it removes only about 45 per cent of the C.O.D. Thus, the paper plant waste persists in the stream farther than is shown by B.O.D. measurements alone.



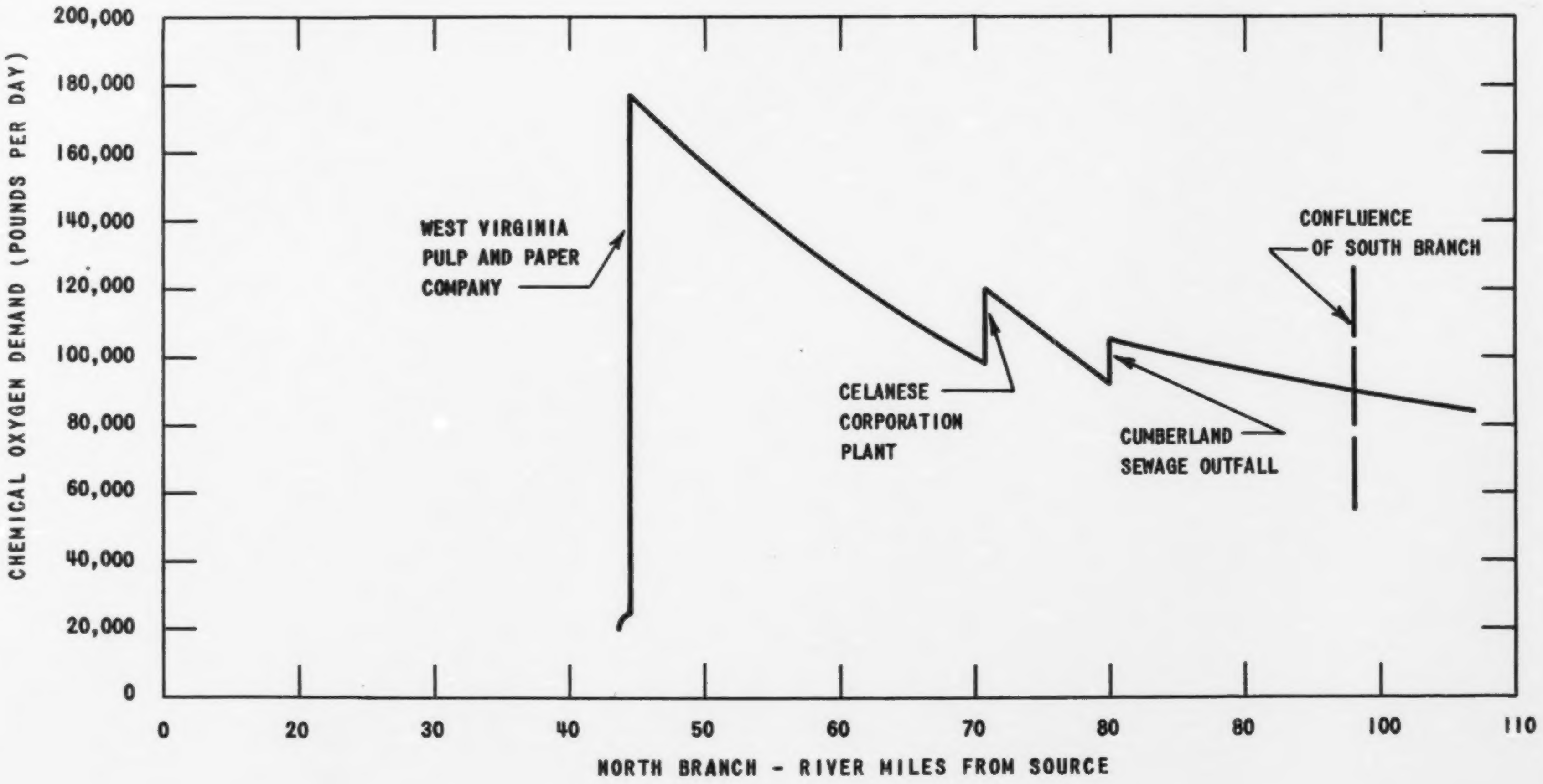
AVERAGE BIOCHEMICAL OXYGEN DEMAND (5-DAY, 20°C.)
(SEPT.-OCT., 1956)

Figure 5



AVERAGE DISSOLVED OXYGEN (SEPT. - OCT., 1956)

Figure 6



AVERAGE CHEMICAL OXYGEN DEMAND (SEPT. OCT., 1956)

Figure 7

Total and suspended solids are shown graphically in Figures 8 and 9. Figure 8 demonstrates that the concentration of total solids and total volatile solids below the paper plant decreases with distance downstream until at Cresaptown these solids concentrations are approximately the same as they were above Luke. The suspended solids present also decrease, but at Cresaptown both total suspended solids and volatile suspended solids occur in appreciably higher concentrations than they did above Luke. Figure 9 illustrates the quantities of total solids present and estimates of the quantities of total solids added to the North Branch between Luke and Cumberland. These estimates are based on the solids discharged by the tributary streams actually sampled in this reach and are probably slightly lower than the actual amounts entering the stream. Obviously, large quantities of solids disappear from the water in these 39 river miles. The major portion settles to the bottom of the stream pools, forming sludge beds which are probably swept downstream when high flows occur. Consideration of Figure 9 indicates that extensive bottom deposits should be present, especially at times of low-flow, in the shorter reach from Luke to Cresaptown.

The alkaline materials added to the stream from the paper mill waste are valuable in this case; they neutralize the acid mine drainage present in the North Branch above Luke.

Waste from the paper plant adds about 90 ppm of color to the North Branch at Luke under the flow conditions found during this survey. As far downstream as Pinto, Md., about 70 ppm of this color persist.

Tannins and Lignins from paper mill waste amounted to about 8,000 pounds per day (as tannins) at Station 9. Almost half of this quantity was still present at Oldtown, Md.

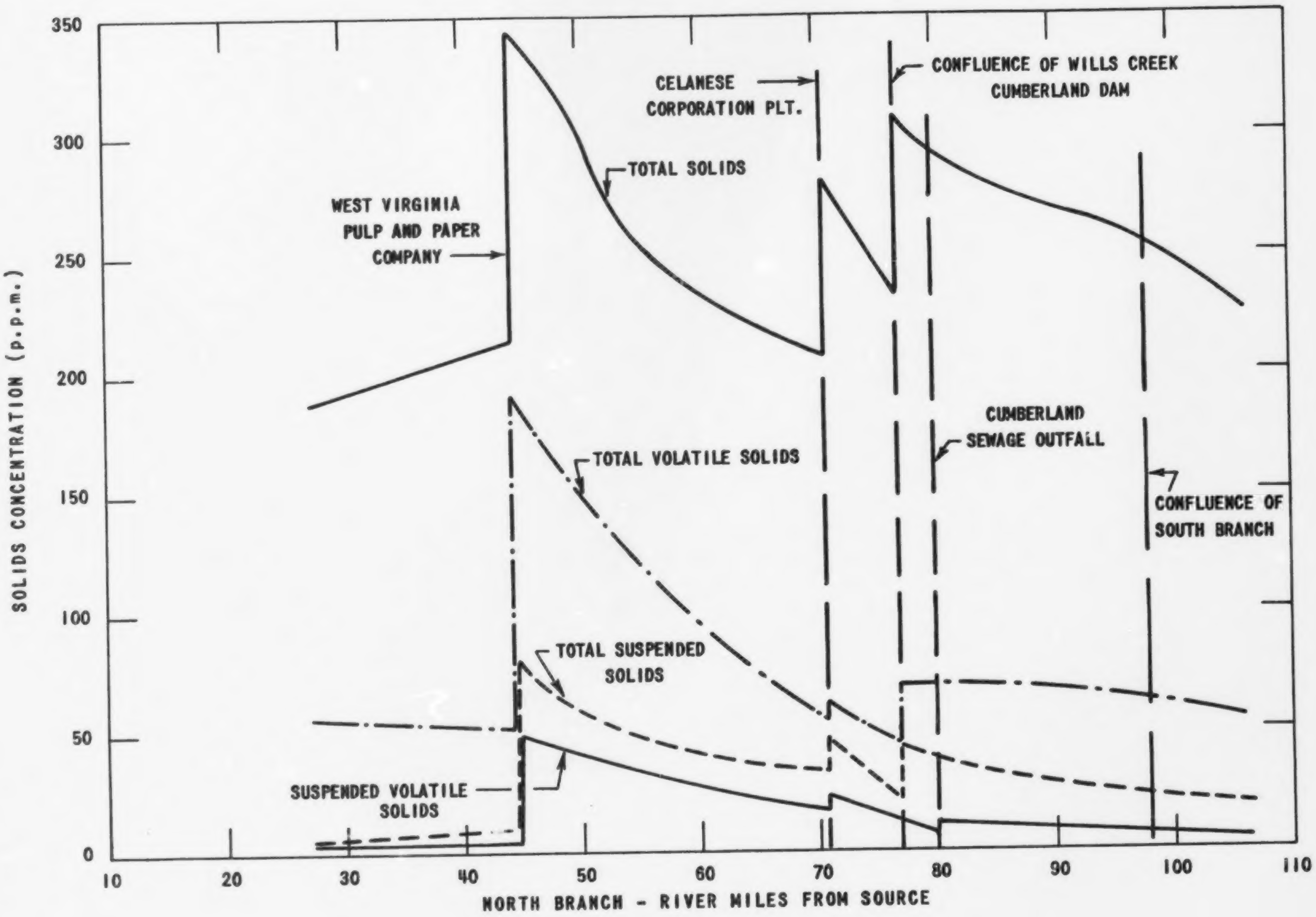
Celanese Corporation of America, Amcelle, Md.

The Celanese plant, located on the North Branch immediately below Cresaptown, Md., manufactures and processes cellulosic organic compounds. It is now operating at half its actual capacity. The principal products are cellulose acetate and cellulose propionate flake for the plastics and film industries, cellulose acetate yarns for the weaving and knitting trade, and various specialty items.

The plant is served by ten principal sewers which discharge untreated process and sanitary waste to the North Branch along a 1500-foot shore. The principal effluents consist of organic wastes and solids (cellulose acetate and cellulose propionate fines and dilute organic acids), fly ash, and washing and cooling water.

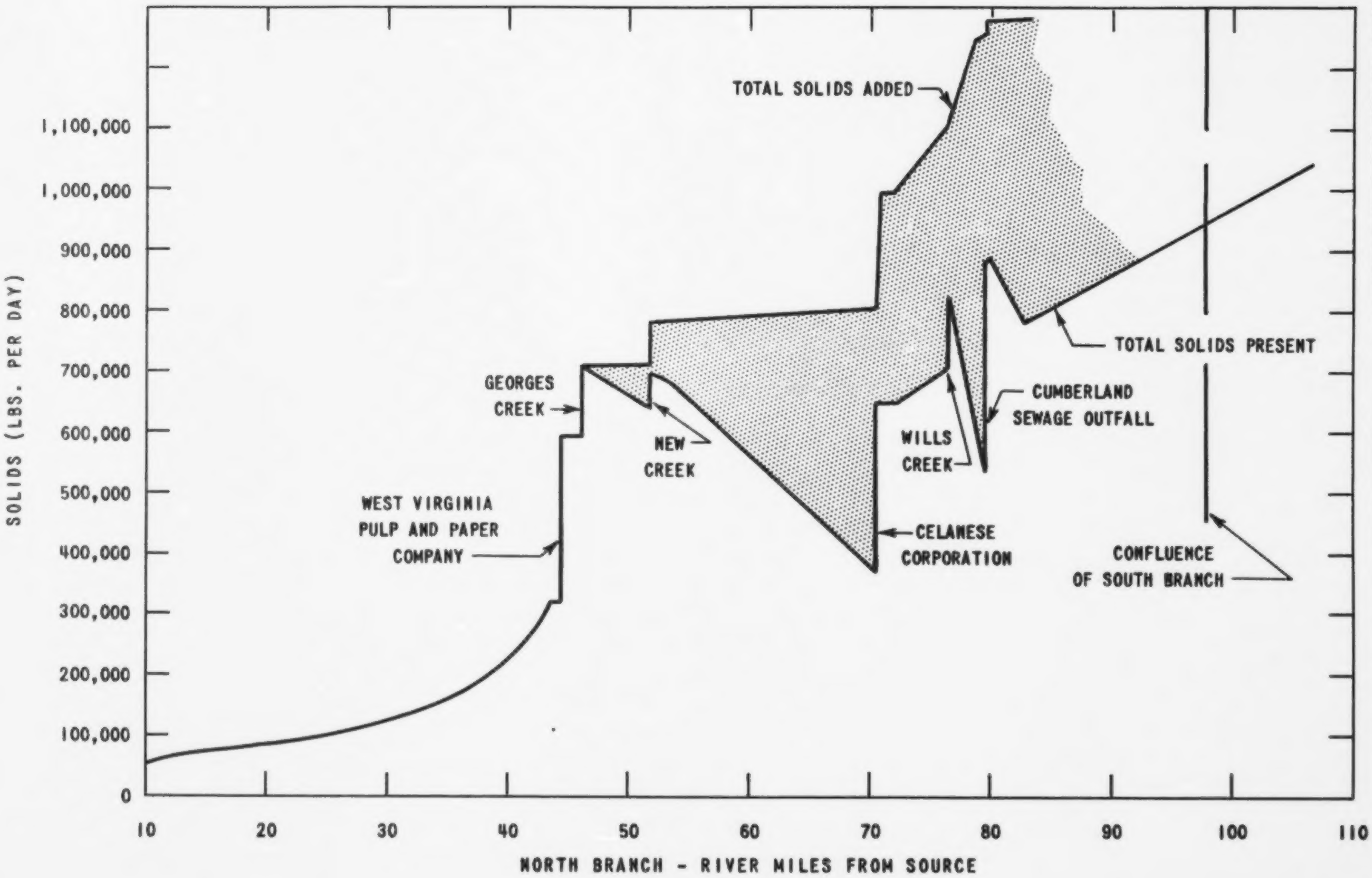
The waste load from this plant was less than had been anticipated, probably because of reduced operation of the plant's production facilities. Table 9 presents averaged data obtained in the routine sampling of the 1956 survey.

The B.O.D. load introduced by the Celanese plant waste is at present about equal in magnitude to that already in the river at that point. This residual load is mainly attributable to the paper mill waste (Figure 5).



AVERAGE SOLIDS (SEPT.- OCT., 1956)

Figure 8



AVERAGE QUANTITIES OF TOTAL SOLIDS (SEPT. - OCT., 1956)

Figure 9

TABLE 9

Measured Waste Loads from the Celanese Plant at Amcelle in 1956 (From Routine Sampling)

	1956 (Sept. 20 - Oct. 15)	(446 cfs)
	lbs/day	ppm
B.O.D. (5-day 20°C)	10,000	4.2
B.O.D. (ultimate)	19,000	7.8
C.O.D.	21,800	9.1
Total Solids	98,000	41
Total Volatile Solids	68,000	28
Suspended Solids	9,700	4
Volatile Suspended Solids	5,000	2.1
Alkalinity	300	0.1

This table is based on the differences between values obtained above and below the plant. The B.O.D. load discharged is equivalent to that from a town of 59,000 population.*

Some solids are discharged by the Celanese plant, mostly in the form of dissolved volatile solids. (Figure 8) The river at the Celanese plant already contains large quantities of solids, and the amount added there is not significant at the present time.

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* Based on 0.17 pounds per capita per day of 5-day, 20°C B.O.D.

Dissolved oxygen in the reach below Celanese was not completely depleted, although low values of less than one part per million were found in the Cumberland Pool (Figure 6). The dam at Cumberland has been relocated in recent years; it is now above the confluence of Wills Creek rather than below. While raw sewage is no longer dumped directly into the Cumberland Pool from Wills Creek; complete D.O. depletion probably would still occur at low-flow or with increased waste discharges from the Celanese plant.

Kelly-Springfield Tire Company, Cumberland, Md.

This plant is situated on the North Branch at the upstream city limits of Cumberland. No industrial wastes are discharged into the North Branch or into the Cumberland sewers, but cooling water is returned to the river.

Potomac Edison Power Company, Cumberland, Md.

This plant, which generates power for the Cumberland area, is located slightly downstream of the Kelly-Springfield plant. It also returns its cooling water to the river but discharges no industrial or other wastes.

Pittsburgh Plate Glass Company, Cumberland, Md.

This plant, located immediately below Cumberland on the North Branch, is not yet in full operation. Its main product will be high-quality plate glass.

Wastes are expected to be primarily wash waters from the grinding and polishing operations. Settling lagoons are being provided to remove suspended solids; this treatment will probably be quite adequate.

A primary sewage treatment plant is also being constructed for sanitary sewage from 600 employees. This plant is suitable for expansion and for the installation of secondary treatment facilities when and if found necessary by the State of Maryland.

Municipal Sewage

The North Branch receives sanitary sewage from virtually all the towns and villages on the watershed; Table 1 shows the sewered population of these communities. Sewage treatment facilities are practically nonexistent. Sewage loads are contributed by the Luke-Piedmont-Westernport district, Keyser, Frostburg, and Cumberland. The waste from the majority of these towns is insignificant in the large quantities of industrial waste present in the North Branch.

Frostburg discharges the majority of its sewage into the headwaters of Georges Creek, the remainder going to Jennings Run; the other communities and isolated homes on the Georges Creek watershed add their waste loads to the same stream. This creates a local pollution nuisance, but most of the load has been either assimilated or deposited before Georges Creek joins the North Branch. A B.O.D. of 2.5 ppm and a D.O. of 9.8 ppm at an average discharge of 22 cfs were present near the mouth.

Wills Creek receives waste from the many small communities to the west and northwest of Cumberland. Near its mouth it carried a B.O.D. load of 2,200 pounds per day at an average concentration of 5.3 ppm. The D.O. was rather high, 9.9 ppm, probably because the creek, like the river, has pools and cascades. Wills Creek formerly carried some waste from Cumberland itself, but interceptor sewers have now been built to carry all waste to the new treatment plant.

Most of Cumberland's sewage and other municipal wastes has been directed into one large sewer which at present flows into the North Branch below the city limits. Ridgeley, W. Va., across the river from Cumberland, discharges untreated wastes from numerous outfalls all along the riverfront. The Cumberland area, with a total equivalent population of about 40,000, currently discharges the largest raw sewage load of any community on the North Branch.

Two composite samples taken in the main Cumberland sewage outfall showed a B.O.D. (5-day, 20°C.) load of 4,500 pounds per day. This load plus the load from one other large outfall and the sewage discharged by Ridgeley, W. Va., makes up the load from the Cumberland area.

The data do not indicate that the sewage discharge from Cumberland increased the river's B.O.D. concentration below the outfall. There was a very slight decrease in B.O.D. from Station 19 to Station 21, 4.6 ppm to 4.3 ppm; over the same reach there was a decrease of 1.5 ppm in D.O., a decrease of 6 ppm in suspended solids, a decrease of 1.8 ppm in C.O.D. and an increase of 3.4 ppm in total alkalinity. These values occurred at an average flow of 575 cfs. Figures 5, 6, 7, and 8 show similar relationships when loads in pounds/day are plotted.

These data indicate that much of the sewage load must be deposited on the stream bed between the outfalls and Station 21. At times of sudden high flow some of this sludge would be resuspended and carried downstream, causing a transient pollution problem in reaches farther downstream. Primary treatment will prevent further deposits of sludge.

DISCUSSION OF DATA FROM OTHER SOURCES

Low-Flow Conditions

Flows in the North Branch Potomac River during dry months are maintained by releases from the Stony River and Savage River Dams. The Stony River Dam, owned by the West Virginia Pulp and Paper Company, has a watershed of 12.2 square miles and a reservoir capacity of 1,500 million gallons. The Savage Dam, completed in January 1952, has a watershed of 105 square miles and a reservoir capacity of 6,500 million gallons. When properly operated, these reservoirs can provide a minimum daily flow of 93 cfs (60 mgd) under drought conditions as severe as those of 1930-31 at Luke, the most extreme on record. The daily flows less than 108 cfs (70 mgd) since the completion of the Savage River Dam are presented in Table 10. These figures came from U. S. Geological Survey records except those for October, November, and December of 1955, which were taken from provisional data supplied from records at the Luke Mill.

TABLE 10

Flows Under 108 cfs in the North Branch
Potomac River at Luke, Maryland

Flow (cfs)	Number of Days in Each Year			
	1952	1953	1954	1955
62 to 68	10	-	-	-
69 to 76	3	2	3	-
77 to 84	18	9	-	-
85 to 91	16	101	4	2
92 to 99	55	55	6	6
100 to 107	14	10	13	18

The inability to maintain 93 cfs in the North Branch during this period was not due to any lack of water in the reservoirs, but to inadequate releasing of this water. Experience in regulating reservoir releases should prevent any future flows less than 93 cfs, so the value of 93 cfs (60 mgd) will be regarded as the minimum flow in the North Branch which may be expected at Luke under present conditions.

There are very few long-term records of flows in the North Branch above the confluence with the Savage River. However, a U. S. Geological Survey gaging station operated for 22 years (1929-1950) at Station 6, Bloomington, immediately preceding the confluence. These flow data have been analyzed statistically to determine how often certain low-flow conditions may be expected to recur at this point. These frequencies were calculated from the minimum daily flow during each year and from the minimum average flow for any seven consecutive days. Table 11 presents the results of this analysis and also some estimates of corresponding flows at Kitzmiller which are discussed in the following paragraphs. The flows at both Bloomington and Kitzmiller are affected by releases at the Stony River Dam.

In 1949 a Geological Survey gaging station was established at Kitzmiller, Maryland, upriver from Bloomington. There are still too few data from this station for a detailed analysis, but Table 12 indicates what low-flow conditions prevailed during the first four years of record.

A comparison of flows ranging from 0 to 19 cfs at Kitzmiller with the corresponding flows at Bloomington indicates that, within this flow

TABLE 11

Recurrence of Minimum Weekly Flows in North Branch Potomac River at Bloomington and Kitzmiller

	Bloomington		Kitzmiller	
Time Interval at which flow will recur (years)	Minimum Daily Flow (cfs)	Minimum Weekly Flow (cfs)	Minimum Daily Flow (cfs)	Minimum Weekly Flow (cfs)
2	30	38	-	-
3	25	33	-	-
4	22	29	-	-
5	20	26	11.8±3.4	15.3±4.5
7	16	22	9.4±2.8	13.0±3.8
10	13	18	7.7±2.2	10.6±3.1

TABLE 12

Low-Flow Ranges
in the North Branch of the Potomac River
at Kitzmiller

Flow Range (cfs)	Number of Days Flow Range Occurred During the Year			
	1953	1952	1951	1950
0 - 9.9	10*	0	0	0
10 - 19	15	14	0	0
20 - 29	40	42	0	1
30 - 39	54	34	16	2
40 - 49	20	23	19	10
50 - 59	10	15	16	28
60 - 69	6	12	8	14
70 - 79	7	4	7	11

* Minimum recorded daily flow = 6.2 cfs, Sept. 30, 1953

range, the flows at the Kitzmiller station are directly proportional to those at Bloomington. This relationship has been used to make the estimates included in Table 11. The limits given with the estimates indicate a 95 per cent certainty that the actual minimum flow will fall within the ranges shown.

Flow records from Luke and from Bloomington covering a period of 23 years have been used to estimate a mean flow under low-flow conditions, in this instance, during flows at Luke of 300 cfs or less. An analysis of these low-flows indicates that flows of 300 cfs or less occur an average of 171 days per year and that the mean flow at Luke during these 171 days is 146 cfs.

Magnitude and Fluctuation of Acid Mine Drainage

In 1938 it was reported* that the three major drainage tunnels in the Georges Creek and Wills Creek Basins carried about 54 per cent of all the acid mine waste entering streams of the North Branch Potomac River Basin: the Midland Drainage Tunnel carried about 4 per cent; the Allegany Water Ditch, about 2 per cent; and the Hoffman Drainage Tunnel, about 48 per cent.

The Interstate Commission on the Potomac River Basin** has quoted a total figure of 172,800 pounds per day of acid entering the streams of the Potomac Basin. This value is based on tests run on mine effluents by the W.P.A. during the mine-sealing program in Maryland in the 1930's. The original data are no longer available for examination, but a comparison between the magnitude of this published result and the magnitude of results from this field survey and from Fuhrman's 1950-52 study indicates that total acidity was probably the criterion for this estimate. Because of variations in experimental techniques and difficulties involved in interpreting the data this is probably a very rough estimate of the actual acid load created by mine waste at that time.

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* Hall, George L., "The Control of Stream Pollution in Maryland From Acid Coal Mine Drainage," Twelfth Annual Conference of the Maryland-Delaware Water and Sewerage Association, 1938.

**Interstate Commission on the Potomac River Basin Preliminary Report on the Potomac River Basin, 1943, p. 79.

The West Virginia Pulp and Paper Company has sampled the North Branch Potomac River immediately above Luke twice a month since 1949 except during a brief period when the plant was shut down. Their data have been analyzed statistically to determine what conditions prevail at this location. Results indicate that the following conditions are typical of the North Branch at Bloomington:

(1) The mineral acidity and total acidity fluctuate widely during an annual interval. (This is also true of mine discharges, as the Mellon Institute found in studying abandoned mines in Pennsylvania.)

(2) The actual acid load at a point in the stream tends to increase as the stream discharge increases, but factors other than discharge appear to exert a controlling influence upon acid load. A complex relationship of acid load to discharge, to duration of high or low-flows, to resuspension and chemical interaction of deposited

iron salts, to sudden increases in flow, and probably to other conditions, appears to exist.

(3) The annual mean total acidity present is about 26,000 pounds per day; for 50 per cent of the year the total acidity varies between 15,000 and 47,000 pounds per day. The total acidity of samples taken over a whole year may range from 3,000 to 200,000 pounds per day.

(4) The pH here falls between 4.0 and 5.1 during 50 per cent of the year. The annual mean pH is 4.5; extremes of 3.0 and 6.9 have occurred.

(5) For one week in any ten-year period, the pH is equal to or less than 2.8 and the total acidity is equal to or greater than 200 ppm. This condition normally exists at times of extreme low-flow.

These conditions indicate that the North Branch at Bloomington can be expected to maintain an appreciable total acidity throughout the year; storing these waters in a reservoir would involve large quantities of water having a pH of 5.1 or less.

Pollution of the Luke-Cumberland Reach in 1952

In the period 1950-52, Ralpn E. Fuhrman, working under the auspices of the Interstate Commission on the Potomac River Basin, conducted a detailed investigation of pollution of the North Branch by industrial wastes. In general, he found conditions similar to those found in the present survey for the Luke-Cresaptown reach. At the time of Fuhrman's study in 1952 discharges in the North Branch were very low, nearly at the minimum flows for the reaches studied. Near Keyser he found D.O. values were approximately 2.5 ppm; at Cresaptown, the D.O. had increased to about 4.5 ppm. His values probably represent typical dissolved oxygen content and recovery during minimum flow. When very low-flows are accompanied by high B.O.D. loads, the dissolved oxygen in some of the pools on this reach may be depleted completely. Septic conditions were present all the way from the Cumberland Fairgrounds, through Cumberland, to Wileys Ford. The D.O. did not reach near-saturation levels until beyond the vicinity of Oldtown.

In 1952, Fuhrman found an ultimate B.O.D. load of 46,200 pounds per day from the Celanese plant. At that time the plant was operating near capacity.

From his data Fuhrman calculated the assimilative capacity of the North Branch for organic pollution loads. These estimates were based on a D.O. depletion in the North Branch to not less than 4 ppm at minimum flow. He calculated ultimate maximum permissible B.O.D. loads for the North Branch as 16,000 lbs/day for the Luke-Cresaptown reach, 13,700 lbs/day for the Celanese-Cumberland sewer reach, and 14,400 lbs/day for the reach below the Cumberland sewer. These allowable ultimate B.O.D. loads were converted to 5-day, 20°C. B.O.D. values by use of Fuhrman's reaction velocity constants. The maximum permissible loads on this basis are 10,900 lbs/day, 11,300 lbs/day, and 10,800 lbs/day, respectively, for the three reaches. These values are presented in Figure 5.

Pollution by Cumberland Sewage in 1953

In October 1953, the Maryland State Department of Health conducted a thorough survey of the effects of the Cumberland sewage discharge on the North Branch from the Fairgrounds (Station 16) to a point just downstream of Station 21. Flows were very low during that period, about 130 cfs at Wiley Ford (Station 19). Figure 10 shows the variations in B.O.D., D.O., and MPN of coliform organisms found in that study.

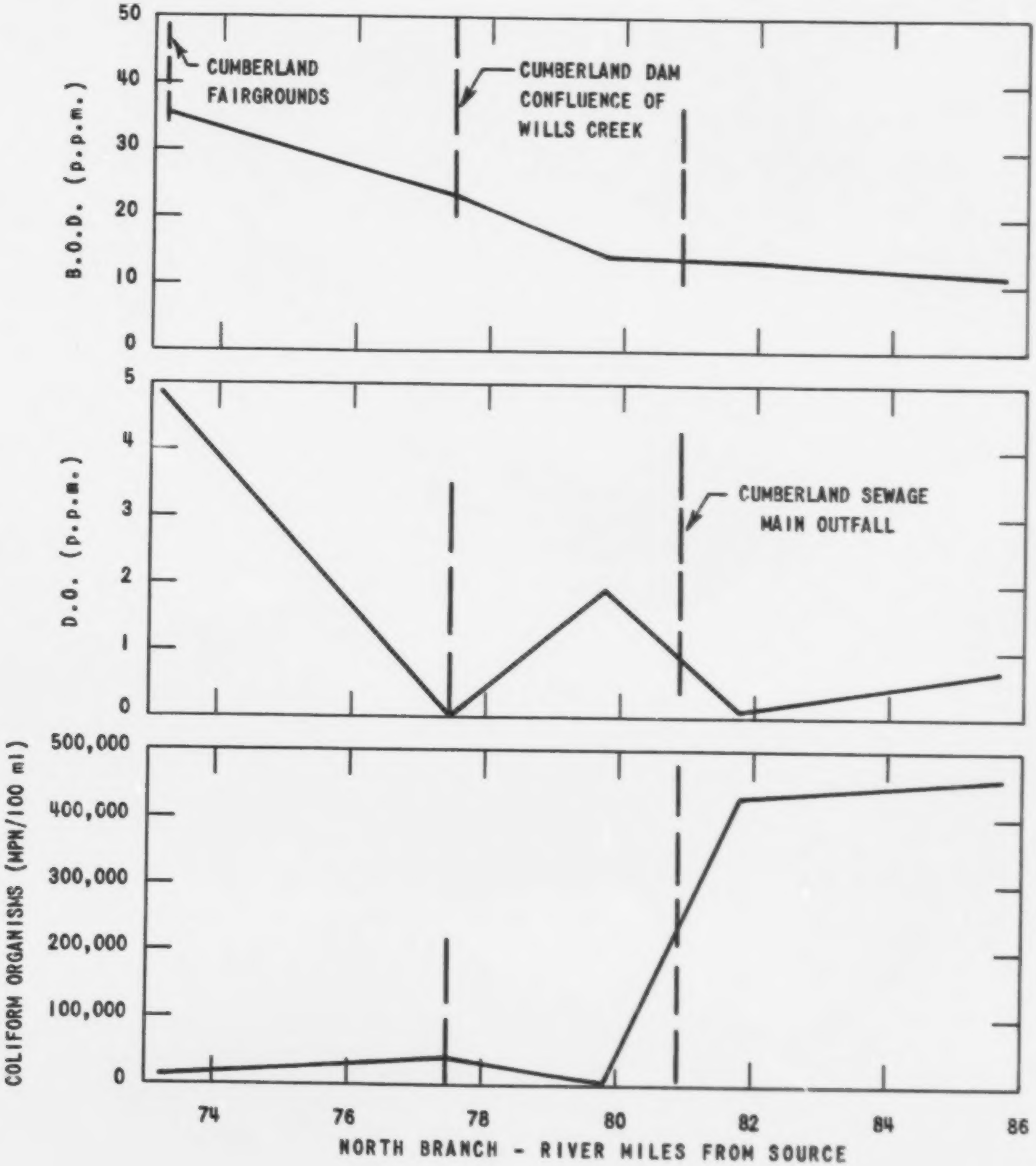
The B.O.D. decreased throughout the reach, rather rapidly from the Fairgrounds to the Cumberland Sewage outfall, then more slowly. These data differ slightly from those of Fuhrman and those of the present survey for the river above and below the Cumberland sewage outfall. It is likely that, at the extreme low-flows during the sampling period in 1953, much of the settleable B.O.D. load was deposited on the stream bed before the downstream sampling station was reached. The dissolved oxygen change shows close agreement with that which Fuhrman found in 1952 for the same reach of river under similar flow conditions. The MPN of coliform organisms, which is a major index of pollution from human waste, shows relatively small concentrations above Cumberland and a very large increase below the Cumberland sewers. Sampling at Oldtown during the same survey shows a median coliform MPN of 15,000, indicating that most of the bacterial contamination had been eliminated by the time that point was reached.

Pollution Abatement Plans

The disposal of acid mine drainage is one problem which has not yet been solved. The amount of acid produced in a mine and the concentration of the acid discharged both vary because they depend upon the ground water supply, which in turn depends upon rainfall. Furthermore, once the exposed surfaces of the mine have been leached as far as the water can penetrate, acid production declines until erosion, abrasion, etc., expose fresh mineral-bearing surfaces. Acid formation has been prevented to some extent by sealing abandoned mines, but the method is difficult, tedious, and limited in application. Acid-bearing streams can be neutralized chemically but only at prohibitive expense.

The complete elimination of downstream effects of acid-mine-drainage pollution now depends upon the dilution effect of increasing flow, combined with neutralization of the acid by the natural alkalinity of inflowing streams and by alkaline industrial wastes.

The West Virginia Pulp and Paper Company plans to expand to double the present plant capacity of about 400 tons per day. At the same time an activated sludge waste treatment plant, expected to cost about 2.8 million dollars, is to be built for treating plant wastes and probably sewage from the neighboring towns. Company representatives anticipate that this degree of waste treatment combined with increased efficiency within the plant will result in a future waste discharge to the stream of not more than 16,000 pounds per day of B.O.D. load (5-day, 20°C) and 34,000 pounds per day of suspended solids. The alkalinity and the color of the waste should not be decreased by this treatment; therefore, while the total amount of polluting material will be decreased considerably, the color of the North Branch will probably be worse than it is at present and the alkalinity of the river will probably increase considerably, perhaps double.



B.O.D., D.O., AND MPN OF COLIFORM ORGANISMS
VICINITY OF CUMBERLAND, OCT., 1953.
(FROM DATA OF THE MD. STATE DEPT. OF HEALTH)

Figure 10

At the anticipated minimum low-flow of 93 cfs, the North Branch below the waste treatment plant's outfall, it is estimated that the maximum concentrations of pollutants will probably be as shown in Table 13. Representatives of the paper company believe that the actual waste loads will be less than the Table 13 figures; since the use of activated sludge for treatment of paper mill wastes is a recent development, a close estimate of the efficiency of the proposed plant is not possible at the present time. For this reason the maximum expected loads are presented.

TABLE 13

Estimated Maximum Future Concentrations of Pollutants in the North Branch Below the Paper Plant Outfall at 93 cfs

	Concentration (ppm)
B.O.D. (5-day, 20° C)	32*
Suspended Solids	68*
Alkalinity	200
Color	300

*Based on waste load estimates of Hazen & Sawyer, Consultants to the West Virginia Pulp and Paper Company.

The City of Cumberland is now constructing a sewage treatment plant for its wastes. The plant will provide primary treatment with chlorination of the final effluent. The City plans to start operations in 1957. It also plans to channel wastes from the entire Cumberland suburban area to this treatment plant during the next few years.

GENERAL DISCUSSION

Comparison of Results

Acid Mine Drainage

The degree of pollution by acid mine drainage has apparently changed in some locations since the 1930s. At that time the Hoffman Drainage Tunnel carried nearly half of all the acid mine drainage in the Potomac River Basin, and the other two drainage tunnels in the vicinity also carried significant amounts of this waste.

At the time of this field survey, greatly different concentrations were found. The Hoffman Drainage Tunnel discharged only small amounts of acid, and the other two tunnels showed no evidence of acidity. Wills Creek, which used to carry large quantities of acid, carried virtually none. Georges Creek still carries a large acid load, although much less than the earlier measurements would indicate.

Comparisons between conditions reported in 1938 and conditions existing in 1956 show a striking reduction in amounts of acid mine waste discharged in the Georges Creek and Wills Creek Basins. The mine-sealing program may be partly responsible for this, but the possibility that the amount of acid formed in an abandoned mine ultimately decreases must be considered. Only intensive sampling for a long time can demonstrate exactly what does happen.

Industrial Wastes

Large differences are immediately apparent between the data on the paper-mill wastes obtained during this survey and the loads estimated by the West Virginia Pulp and Paper Company from long-term sampling of the river and from samples of their plant effluents. There are probably several reasons:

(1) The Public Health Service samples used were 24-hour composites of the river above and below the plant; their compositions are more representative of the actual waste load in the river at that time than are grab samples taken at intervals.** Note that the average waste load of eight grab samples taken during the five-week sampling period was about 10,000 pounds per day less than that of the three composite samples taken during the same period.

(2) During the survey, the paper plant was operating above capacity most of the time, according to plant representatives. The Company has not released production figures.

(3) The data obtained by the plant were accumulated over a long time, probably including periods of widely varying production. An average of such data would not necessarily be applicable when a particular time interval, such as the five weeks of this survey, is being studied. To relate such data to a limited period, the production volume corresponding to given waste loads should be known and used.

(4) Under some conditions the nine sewers regularly sampled by the plant carry less than the 99 per cent of the waste load as is believed by the Company.

** Composite samples and grab samples differ most noticeably immediately below a source of pollution; as slugs of waste go downstream they tend to spread uniformly along the river, so that the farther below a source of pollution a sample is grabbed, the more representative it becomes of daily average conditions.

The data obtained during this survey have been discussed with responsible representatives of the West Virginia Pulp and Paper Company and with a representative of Hazen & Sawyer, consultants to the Company. These representatives feel that the waste loads found during this survey do not represent the normal plant discharge and that the facilities for waste treatment now being planned will be able to accomodate any wide fluctuations in plant discharge.

For several years since Fuhrman's study, the Celanese plant has been operating at greatly reduced production volumes. The ultimate B.O.D. is now about 19,000 lbs/day instead of the 46,200 lbs/day found in 1952.

The waste load discharged by the Celanese Corporation is still greater than the North Branch can assimilate, according to Fuhrman's analysis. Under present operating and flow conditions the equivalent of primary treatment of the plant waste would be enough to reduce the waste load to levels which can be assimilated by the stream. If full-scale operation is ever resumed, more extensive treatment would be indicated. Fuhrman states that a B.O.D. reduction of 70 per cent would be required; this does not seem unreasonable. Such a reduction would require treatment equivalent to that obtained in a secondary sewage treatment plant.

Production at the Celanese plant is not expected to increase; if it does, however, it is assumed that suitable waste treatment facilities will be provided to conform with the requirements of the Maryland Water Pollution Control Commission

Municipal Wastes

The data of Fuhrman, the Maryland Department of Health, and the Public Health Service all agree on the conditions below the Cumberland sewage outfall.

Summary of Present and Estimated Planned Conditions With Existing Minimum Flow Conditions

The Savage River Dam can now be expected to maintain a minimum flow of 93 cfs at Luke. At extremely low-flows, dissolved oxygen levels can be expected to be fairly low in the North Branch below Luke, even after a waste treatment plant has been installed by the West Virginia Pulp and Paper Company. Plant representatives estimate that a critical D.O. of 4 ppm or more can be expected from a waste load of 16,000 pounds per day of 5-day, 20°C B.O.D. Below the Celanese plant, total depletion of D.O. can be expected in the Cumberland Pool under anticipated loads. Below Cumberland, a D.O. of less than 4 ppm should not occur, according to Fuhrman's analysis of the assimilative capacity of the North Branch.

Table 14 summarizes present waste load concentrations at minimum flow and estimated future minimum flow concentrations in the North Branch. Flows at points downstream from Luke are based on information supplied by the Corps of Engineers indicating an increase of 24 cfs from Luke to Cumberland at minimum flow, most of this from the Wills Creek drainage area. The minimum flow at Station 16 was estimated as 100 cfs from this information. Flows at points upstream from Luke are estimated from the 10-year minimum weekly flow at Station 6.

The concentrations estimated in Table 14 are derived from these assumptions:

(1) In the streams above Luke, the quantities of materials carried, other than acid mine drainage, do not change appreciably; the measurements of the 1956 survey are typical.

(2) For estimating the amount of acid mine drainage above Luke, the statistical correlation of pH and total acidity at Luke from data of the West Virginia Pulp and Paper Company is applicable. The acid discharge at Kitzmiller is the same fraction of the acid discharge at Bloomington as it was in 1956.

(3) The West Virginia Pulp and Paper Company operates a waste treatment plant which will reduce the B.O.D. load to a maximum 16,000 pounds per day and the suspended solids to a maximum 34,000 pounds per day. Alkaline materials and tannins and lignins will pass through the plant unchanged.

(4) Production at the paper mill is about 800 tons per day.

(5) The population of the Luke-Piedmont-Westernport area is increased by 2,000.

(6) The waste from the Luke paper mill is 90 per cent dissipated in the stream before the Celanese plant is reached. This is based on Fuhrman's analysis of stream flow conditions.

(7) The waste load from the Celanese plant is still similar to the present load. If production increases, suitable waste treatment will be required by the Maryland Water Pollution Control Commission.

TABLE 14

Estimated Present and Near-Future Waste Load Concentrations in the North Branch Potomac River at Present Minimum Flow Conditions*

	Present Load (ppm)**	Future Load (ppm)**
Station 5 (Kitzmiller)		
B.O.D. (5 Day, 20°C.)	11	11
Total Acidity	260	260
pH	2.8	2.8
Suspended Solids	85	85
Dissolved Iron	9.4	9.4
Dissolved Manganese	7.1	7.1
Color	10	10
Station 6 (Bloomington)		
B.O.D. (5 Day, 20°C.)	10	10
Total Acidity	200	200
pH	2.8	2.8
Suspended Solids	93	93
Dissolved Iron	7.6	7.6
Dissolved Manganese	5.5	5.5
Color	10	10
Station 9 (Westernport)		
B.O.D. (5 Day, 20°C.)	98	34
Total Alkalinity	123	210
pH	7-8	7-8
Suspended Solids	255	110
Dissolved Iron	2	2
Dissolved Manganese	1.6	1.6
Dissolved Tannins and Lignins	17	33
Color	380	760

TABLE 14 (Con't.)

Estimated Present and Near-Future Waste Load Concentrations in the North Branch Potomac River at Present Minimum Flow Conditions*

	Present Load (ppm)**	Future Load (ppm)**
Station 16 (Fairgrounds)		
B.O.D. (5 Day, 20°C.)	50.5	24.1
Total Alkalinity	160	240
pH	7-8	7-8
Suspended Solids		120
Dissolved Iron	5.1	5.1
Dissolved Manganese	2.5	2.5
Dissolved Tannins and Lignins	14	28
Color	340	690
Station 21 (Below Cumberland)		
B.O.D. (5 Day, 20°C.)	23	14.2
Total Alkalinity	190	260
pH	7-8	7-8
Suspended Solids		71
Dissolved Iron	4.1	4.1
Dissolved Manganese	2.7	2.7
Dissolved Tannins and Lignins	9.6	19.3
Color	280	550

* The differences between the river water above the waste outfalls and Savage River water are so small compared to the pollution load soon to be introduced, that a negligible error results from assuming the diluting waters all have the water quality of the Savage River.

** Except pH, which has no units

(8) Waste load from the Celanese plant is reduced 65 per cent when the river reaches the Cumberland sewage outfall.

(9) The Cumberland sewage treatment plant is in operation, removing 35 per cent of the B.O.D. load and 90 per cent of the coliform organisms.

(10) Waste loads from other sources are similar to present loads.

The estimates presented in Table 14 indicate that, even after the planned waste treatment facilities are completed, the North Branch will not meet the minimum criteria for Class D streams during times of minimum flow for many miles below Cumberland

Quality of Water Stored in Proposed Reservoirs

Three potential damsites on the North Branch watershed are considered. The approximate locations of these dams and the water quality to be expected in the pools formed behind these dams are given in Table 15.

In estimating what water quality can be expected in these lakes, the water quality found on the 1956 stream survey is assumed to be representative, except in the case of acid mine drainage. Since the three streams contain only minimal organic pollution, this is believed to be a valid assumption. The concentration of acid mine drainage in the North Branch at Bloomington is assumed to be the mean of the acidity concentrations found over a seven-year period, as discussed previously. The pH and the total acidity are assumed to be similar means weighted according to flow. The acidity and pH of the North Branch vary tremendously under unregulated flow conditions, as was also pointed

TABLE 15

Quality of Water in Proposed Reservoirs on the North Branch Watershed

Dam Location		Savage River above Present Pool	Stony River below U.S.Highway 50	North Branch above Bloomington
B.O.D. (5 Day, 20°C.)	(ppm)	0.6	0.8	0.8
Total Solids	(ppm)	92	150	170
Total Fixed	(ppm)	48	95	107
Suspended Solids	(ppm)	4.8	15	11.6
Total Alkalinity	(ppm)	19.0	8.1	-
Total Acidity	(ppm)	-	1.6	14
pH	(ppm)	6.9	6.5	5.0
Dissolved Iron	(ppm)	0.09	0.8	0.7
Dissolved Manganese	(ppm)	0.10	0.16	0.6
Color	(ppm)	14	40	5

out earlier; however, if the river is impounded, acidity and pH in the reservoir should approach these mean values.

Savage River Site

For good water quality, the Savage River site is the best of the three considered: the B.O.D. is very low; the solids content is low; the pH is approximately neutral; some alkalinity is present, more than at any of the other sites; color, dissolved iron and manganese are extremely low. This water nearly meets drinking water standards;

Westernport has used water from the existing Savage River Dam without extensive treatment since the dam was finished.

Stony River Site

The Stony River site would also provide water of a very good quality: in B.O.D. and pH it is comparable to Savage River water; the solids content is somewhat higher; the alkalinity is about half that of Savage River water; color, iron, and manganese are too concentrated for this water to be used as a municipal supply without some treatment.

North Branch Site

The North Branch site must be regarded as the least suitable of the three. The river at Bloomington is a very clean stream, except for its acid mine waste. To use this water as a municipal supply, the acid must be removed and the iron and manganese content reduced.

Although the amount of acid carried by the river fluctuates with changes in stream flow conditions, the data available do indicate that upstream from Luke the river is normally acid. Should a reservoir be constructed here, the impounded waters would probably have a pH near 5 most of the time, assuming that the waters were thoroughly mixed. This pH is apparently not lethal to mature freshwater fish unless other conditions which inhibit fish life are coexistent.* At an average pH of 5 in well mixed waters, some less sensitive aquatic life can flourish.

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* Doudoroff and Katz, "Critical Review of Literature on the Toxicity of Industrial Wastes and Their Components to Fish." Sewage and Industrial Wastes, 22, No. 11, 1451-1452 (1950).

Reservoirs frequently stratify when the inflowing streams and the impounded waters have different temperatures. Stratification normally occurs in summer and winter, mixing in spring and autumn. Seasonal stratification here would produce different acidities at different levels. If large releases were required when complete stratification existed, a different acid concentration would enter the river as each level was discharged. As low-flows in the North Branch usually occur in autumn, during or immediately after the autumn mixing, acid stratification would not present a major discharge problem.

Waters at a pH near 5 tend to corrode metal or concrete structures submerged for long periods of time. There are very few statistics on this kind of corrosion; the amount of damage seems to depend on local conditions and, therefore, cannot be estimated.

Effects of Low-Flow Augmentation on Water Quality

Low-flow augmentation from a new reservoir above Luke will affect acid mine drainage in the North Branch in two ways: the acid will be diluted, and the diluting waters will neutralize some acid with their natural alkalinity. The quality of the released waters and, consequently, the magnitude of their effects will depend upon where the dam is located; in turn, the site will determine how many miles of the stream will be improved before the paper plant wastes neutralize the acid completely. In estimating the effects at each projected damsite, the impounded waters will be assumed to retain the characteristics listed in Table 15.

Figure 11 illustrates the changes in total acidity concentration that can be expected immediately above Luke when minimum flow in the

North Branch (93 cfs) is being supplemented by discharge at various rates from dams at each of the sites being considered. No alteration of acidity will be apparent beyond Luke, but changes in the North Branch load will first appear in these places: from a Stony River dam, at the confluence, a few miles above Kitzmiller; from a Bloomington dam, in the upper reaches of the reservoir there; and from a Savage River dam, at the confluence of the Savage River.

The relative effectiveness of each of the three dams in alleviating pollution by acid mine drainage under the minimum flow conditions can be seen in Figure 11. The differences in acidity at Luke are governed by the acidity or alkalinity of the reservoir waters. The curves in Figure 11 are extended beyond the discharges of which each dam is capable in order to illustrate the differences in function and character of the discharges from each dam and how the relationships change when various discharges are made from the dams.

At the smaller degrees of augmentation, of which the Savage River Dam and Stony River Dam are capable, Figure 11 shows that the North Branch Dam discharges of the same amount would result in a lower total acidity at Luke. The reason for this lies in the difference in operation of the dams. The North Branch Dam operates by storing up the highly acid waters entering the reservoir during periods of low-flow and replacing them with a discharge of less acid water from the vicinity of the dam. The other two dams operate by diluting the highly acid water flowing in the North Branch during times of low-flow. If these dams were capable of greater discharges, they would be increasingly effective as higher degrees of augmentation were obtained.

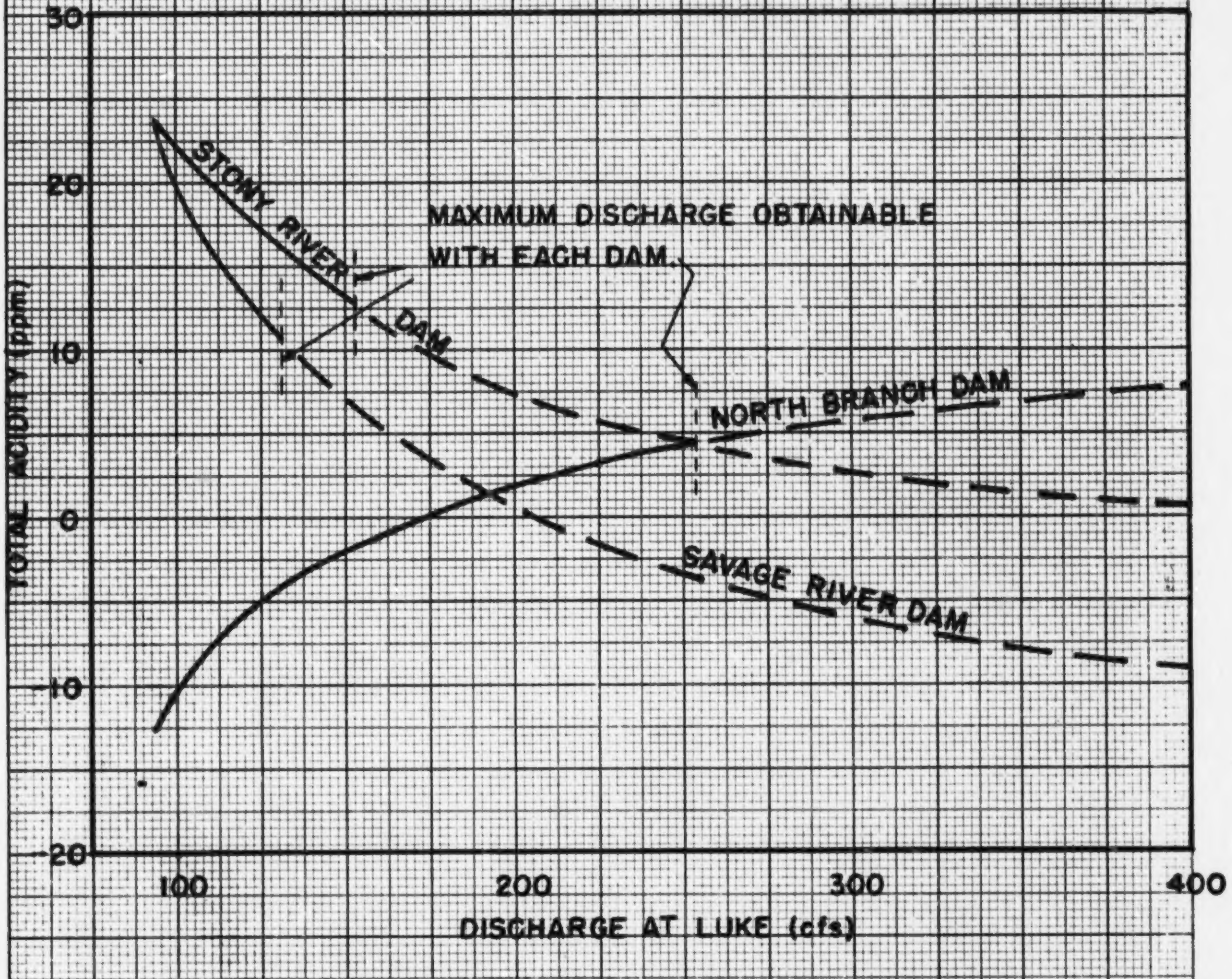

FIGURE 11. ESTIMATED TOTAL ACIDITY IN THE NORTH BRANCH AT LUKE WITH MINIMUM DISCHARGE AUGMENTED BY DISCHARGES FROM EACH OF THREE DAMS.

In considering combinations of the three dams, it should be noted that the acidity at Luke would depend on the rleative volumes of the water used from each reservoir at various times, and upon the fact that the Stony River Dam would discharge into the North Branch Reservoir while the Savage River Dam would then dilute the releases from this dam. For combinations of these dams the acidity at Luke would run from 0 to 5 ppm at discharges greater than 200 cfs at Luke. This, of course, applies only to augmentation of the base 93 cfs flow to the augmented discharge.

Because the highly alkaline paper mill wastes effectively neutralize the acid present in the river at the outfalls, acid mine drainage is not a significant problem below the paper plant. Benefits of low-flow augmentation for the stream down river from Luke must be estimated from the decreased pollution as wastes are diluted by increased river discharge, and from the increased quantity and the improved quality of the water available downstream.

Figure 12 illustrates how augmenting minimum flow at Luke (93 cfs) affects the concentrations of B.O.D. immediately below the paper plant. Similar curves apply to other points along the North Branch; those for B.O.D. at Stations 16 (below Celanese) and 21 (below Cumberland's sewage outfall) have been included. A continuous minimum flow of about 1000 cfs at Luke would be necessary for the North Branch between Luke and Cumberland to meet the Class D standards of the Interstate Commission on the Potomac River Basin.

When B.O.D. removals greater than 85-90 per cent are required, the cost of waste treatment increases out of all proportion to the amount of waste removed. In such cases it is economically impractical to provide conventional types of waste treatment, and dilution of the secondary plant effluent with clean water is the most economical way of reducing the waste concentration. The supplying of additional dilution water then provides stream water quality improvements which are not obtainable in any other way.

The three dams considered here could not provide the 1000 cfs necessary for dilution of the effluent from the presently planned waste treatment plants. Flow augmentation within the capabilities of the proposed reservoirs could, however, be combined with some additional waste treatment to attain Class D stream quality between Luke and Oldtown.

Figures 11 and 12 demonstrate that, as dam releases increase the flow at Luke, each new dilution improves water quality considerably less effectively than the preceding dilution does. For example, Figure 12 shows that, although an increase in continuous minimum flow from 200 to 300 cfs reduces the B.O.D. at Station 9 by 5 ppm, another increase to 400 cfs reduces the B.O.D. by only 2.5 ppm. Because each flow increase costs more and accomplishes less, the unit cost of pollution abatement by flow augmentation increases as low-flow augmentation increases. To determine an optimum continuous flow in the North Branch, the costs of successive increases in continuous flow must be weighed against the pollution abatement benefits derived from each increase.

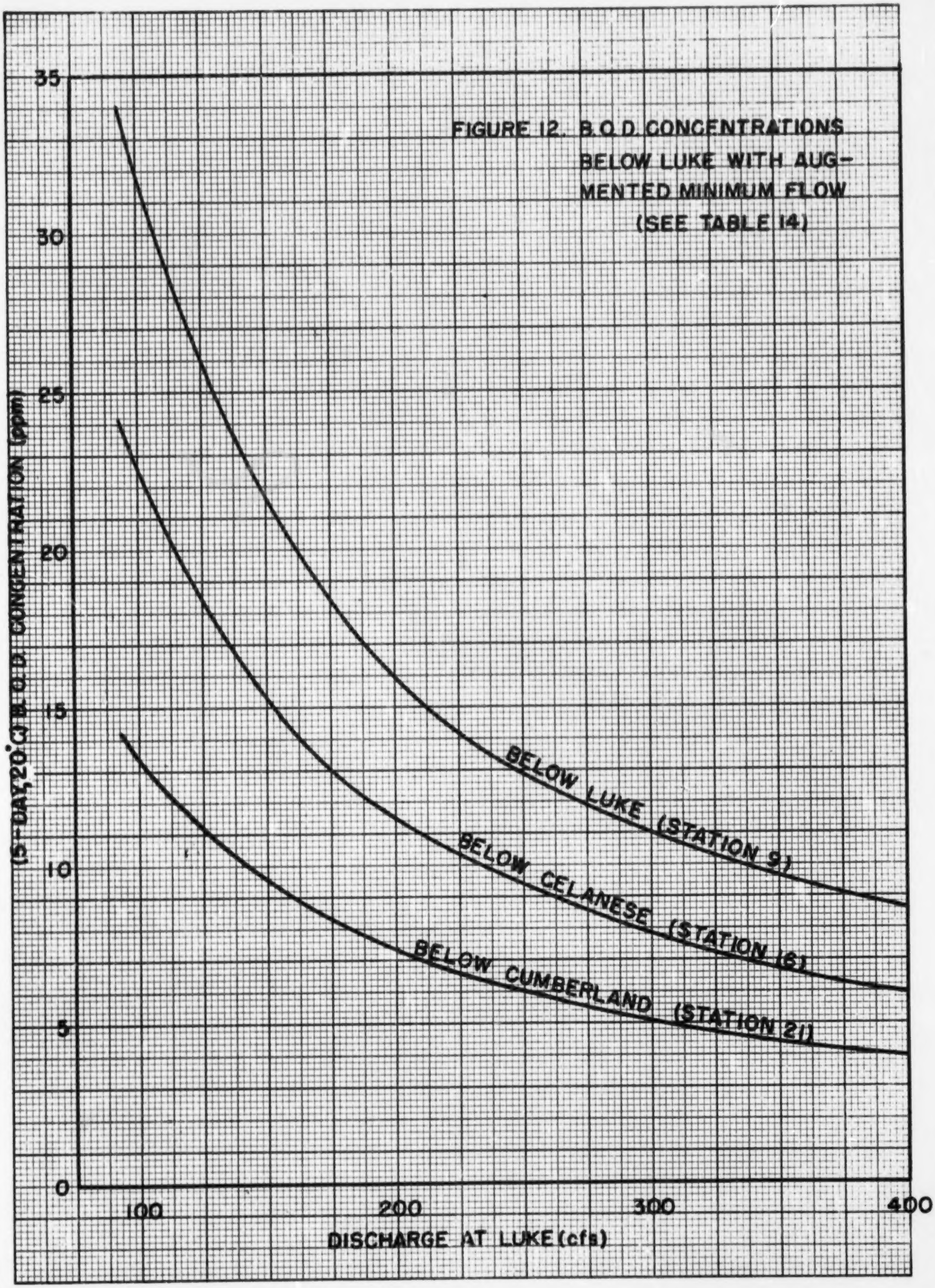

FIGURE 12. B.O.D. CONCENTRATIONS BELOW LUKE WITH AUGMENTED MINIMUM FLOW (SEE TABLE 14)

Estimates of Monetary Benefits Attributable to Low-Flow Augmentation

Benefits from the Reduction of Acid Mine Drainage Concentration

In estimating benefits attributable to reducing the acid load in a stream, the damage caused by the waste must be considered. On the reach of the North Branch which would be affected by releases from the three projected damsites, the only major consumer of acid water is the West Virginia Pulp and Paper Company. Since no other users would be affected by reductions in acid mine waste loads, no tangible damages caused by the presence of acid can be assigned to other entities.

The tangible monetary benefits of reducing acidity concentrations can be estimated for each dam as the reduction in the cost of neutralizing chemicals needed by the paper plant. Because the waters stored in each reservoir will have a different acidity or alkalinity, the benefit attributable to each dam will be different.

The cost of neutralizing North Branch Water has been estimated from (1) the quantity of the chemicals used by the plant during 1956; (2) the acid waste concentration in the North Branch during the 1956 field survey; and (3) the frequency with which total acidity concentrations occurred during seven years of sampling at Luke by the plant. The total acidity frequency for flows less than 300, 200, 150, and 100 cfs was used to calculate the number of days per year that each acid concentration may be encountered: concentrations, days of occurrence for each concentration, and the amount of water which will be used by the plant after its expansion is complete were used to measure the total amount of acid treated per year. From the chemical cost per unit of total acidity (established from the quantity of chemicals used during the sampling period and the acidity data from the survey) the cost of treatment by the expanded paper plant during typical low-flow conditions could be estimated.

The benefits attributable to the reduction in neutralization cost were calculated separately for each proposed damsite. Each of the total acidity concentrations from the mill data was recalculated as if the flow had been diluted to 300 cfs, 200 cfs, 150 cfs, and 100 cfs with water from the reservoir. This procedure is illustrated in Figure 13. The new total acidity frequency was used like the frequency for unaugmented flows to derive the total amount of acid to be treated by the plant under improved conditions for the anticipated discharges from each reservoir. The resulting decreases in acid treatment were then converted to equivalent decreases in cost of the treatment required after the mill has expanded. These figures are regarded as the benefits attributable to reduced costs for water treatment at the West Virginia Pulp and Paper Company from the independent operation of each dam; these benefits are:

Stony River Dam (for 60 cfs from the dam) . . . . . $23,000 per year,
North Branch Dam (for 170-207 cfs from the dam)* $58,000-$63,000 per year,
Savage River Dam (for 45 cfs from the dam) . . . . . $25,000 per year.

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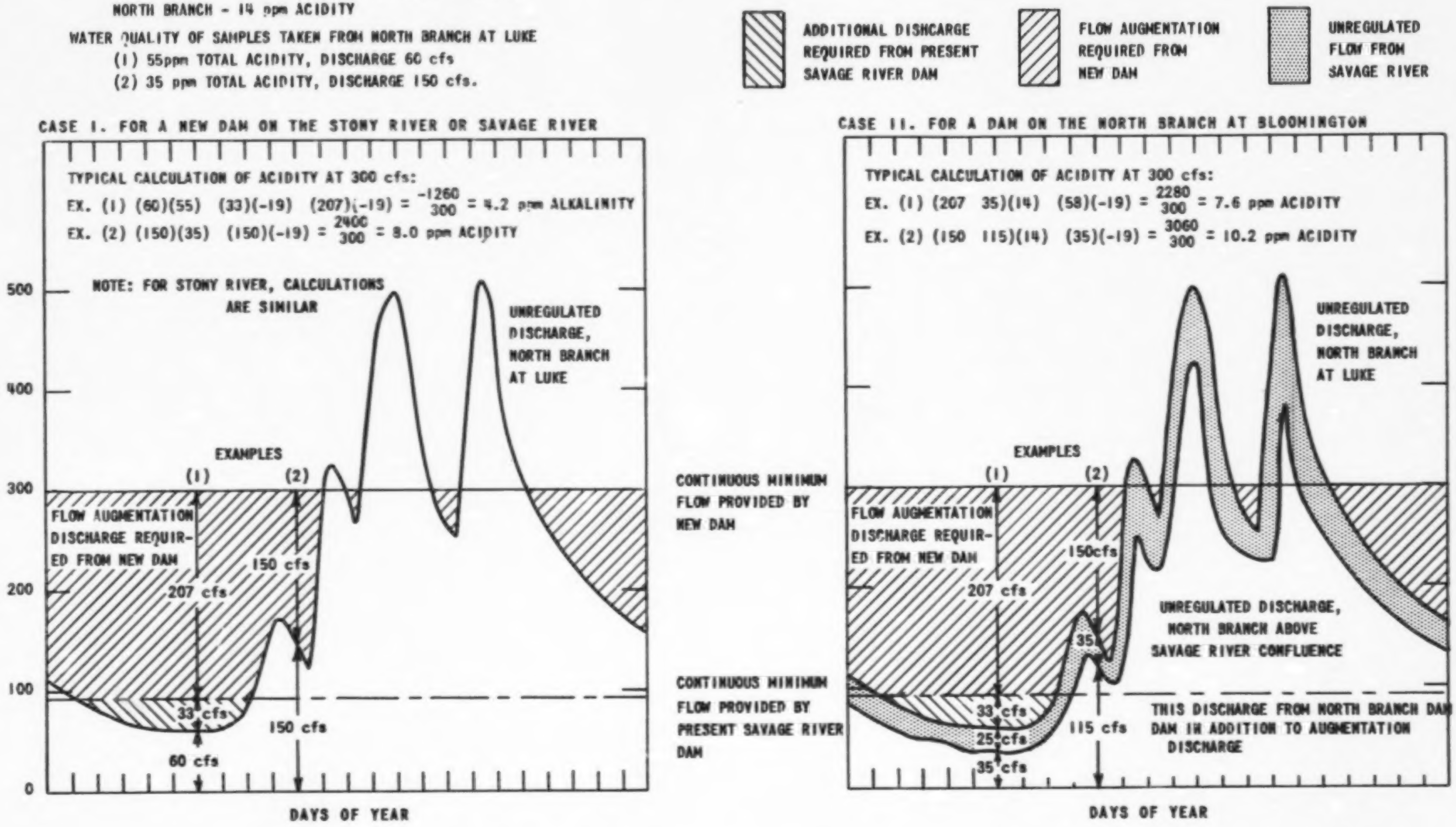
* Allowance has been made for the fact that some of the water discharged from this dam must be used to make up the 93 cfs present minimum discharge at Luke.

EXAMPLES:
WATER QUALITY OF DAM DISCHARGES:
SAVAGE RIVER - 19 ppm ALKALINITY
STONY RIVER - 1.6 ppm ACIDITY, 8.1 ppm ALKALINITY
NORTH BRANCH - 14 ppm ACIDITY
WATER QUALITY OF SAMPLES TAKEN FROM NORTH BRANCH AT LUKE
(1) 55ppm TOTAL ACIDITY, DISCHARGE 60 cfs
(2) 35 ppm TOTAL ACIDITY, DISCHARGE 150 cfs.



HYDROGRAPH ILLUSTRATING FLOW AUGMENTATION REQUIREMENTS AND RESULTING ACIDITIES

Figure 13

If the Savage River and Stony River dams are operated together, or if the Savage River dam is operated in conjunction with the North Branch dam, the benefits from the combination will be the sum of the individual benefits from each dam. If the Stony River dam is operated with the North Branch dam, no benefits due to acidity reduction can be credited to the Stony River dam.

These estimates are based on the cost of chemicals as of February 11, 1957, and on the assumption that the acidity in the North Branch is neutralized by the diluting waters to the full extent of the natural alkalinity of these waters.

Should a dam be built at Bloomington, special protective measures would probably be required to mitigate damage from impounded acid waters thereby reducing the benefits attributable to the construction and operation of this dam. If adequate precautions are taken in the design and operation of the dam, it is likely that any acid damage would be very small.

Reduction of acid-mine-drainage pollution in the North Branch to the extent expected from the flow augmentation recommended here will also produce large but intangible benefits. The environment for aquatic life might improve enough to support some of the hardier species of fish. Recreational development may eventually be feasible. No major industry is likely to locate along the North Branch above Bloomington since the valley is quite steep and offers little land suitable for construction.

The acid mine drainage problem has discouraged efforts to reduce other forms of pollution, particularly organic contamination. There is little incentive to treat sewage or organic industrial waste only to maintain a sterile stream which can only be used to carry off more acid mine waste. Any reduction of the acid concentration in the North Branch will be helpful in reducing this reluctance to improve the water quality below Luke.

Benefits from Reduction in Temperature of the North Branch above Luke

The low-flow augmentation releases from a reservoir are generally obtained from the deeper parts of the pool. In such cases the water released from the dam is considerably cooler in the summer and fall months than the water normally discharging through the free-flowing stream. The use of this cooler water for condensing and cooling purposes permits more efficient operation of heat transfer equipment and a saving in operating and maintenance costs which can be shown as an annual benefit to the plant concerned.

In this case the West Virginia Pulp and Paper Company is located near the sites of two possible dams, the North Branch Dam at Bloomington and the new Savage River Dam which will discharge through the present Savage River Dam. The Stony River Dam is so far upstream that it is reasonable to assume that the water discharged from this dam will have reached a normal equilibrium temperature with the atmosphere by the time Luke is reached. In the event that the North Branch Dam and the Stony River Dam are used in combination there would still be no benefit assignable to the Stony River Dam since the temperature of the water released from the North Branch pool would not be decreased by the Stony River water.

A new dam on the Savage River would discharge cool waters into the present reservoir instead of the present warm surface waters and this would result in even cooler waters being discharged below the dam than are discharged at present. Data from six years sampling by the West Virginia Pulp and Paper Company have provided data on temperatures at Luke before and after the present dam was in operation. An annual temperature profile for these two conditions was drawn and the effects of additional cool water on North Branch temperatures determined by extrapolation. The temperature of the water discharged from the dam was assumed to be the mean annual air temperature for the region (53°F).

The North Branch Dam was assumed to discharge water at 53°F. for the low-flow period. The temperature of the free flowing stream was assumed to be equal to the mean monthly air temperature. This was found to agree closely with the data from the paper company.

The increased efficiency of the plant's cooling water was measured by using a value of $.20 per MGD per °F. reduction for the decrease in pumping costs. This value was given by industries in similar studies on the Allegheny River Basin.

The increased efficiency of power generation was estimated using data on 54 modern steam power stations as presented in Electrical World, V 144, Oct. 17, 1955, page 127-46. An average heat rate of 12,000 Btu/KWH was assumed, and the value of the increased power generating capacity was estimated at 6.3 mills/KWH for annual cost. The estimate was based on the assumption that the power-generating capacity of the plant will be about doubled when the plant expansion is completed and that the power plant operation included total steam condensation. The total annual benefits due to temperature reduction are then:

Savage River Dam (45 cfs).	$120,000
North Branch Dam (170-207 cfs) . . .	$246,000
Stony River Dam (60 cfs)	None

Some industrial power plants do not condense all of the exhaust steam but use it for process purposes. This results in a higher heat rate, estimated in the *Chemical Engineers' Handbook* as around 25,000 Btu/KWH. A more accurate estimate of this value would require information on the exact methods of operation employed in a specific plant. The total benefits due to temperature reduction calculated on this basis are:

Savage River Dam (45 cfs)	62,000
North Branch Dam (170-207 cfs)	125,000
Stony River Dam (60 cfs)	None

This latter method is used for the estimated reimbursable benefits for temperature control, while the former method is used in estimating the total tangible benefits.

Benefits From Reduction in the Degree of Pollution from Municipal and Industrial Wastes above Cumberland

Although increasing the minimum flow in a polluted stream contributes to pollution abatement, mere dilution of the waste load cannot be considered a method for treating waste. In streams containing effluents already treated to remove those substances which must be kept from surface waters*, dilution can produce an improved water quality equivalent to that in an undiluted stream containing waste loads which have received additional treatment. For example, primary treatment of sewage before it enters a stream is believed necessary before benefits can be credited to dilution flows as equivalent treatment plant costs. Dilution of a stream containing primary-treatment-plant effluent may achieve the same results in stream recovery as secondary sewage treatment without dilution. This alternative effect is assigned monetary benefits equal to the cost of the processes it replaces.

In some cases dilution can accomplish waste reductions which cannot be economically accomplished by conventional waste treatment processes. Where B.O.D. removals greater than 85-90 per cent are required, the cost of the necessary treatment facilities increases enormously for the removal of each successive increment of B.O.D. In such cases dilution of the treatment plant effluent is frequently the only economically practical method of reducing the concentration of polluting materials in the receiving stream.

Estimating the cost of industrial-waste-treatment processes is difficult, especially when the more conventional processes are not effective, so that special equipment or modified production techniques, or even both, must be used. The cost of removing oxygen-depleting industrial wastes from plant effluents is generally based on the cost of removing a similar amount of oxygen-depleting substances from domestic sewage.

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* In general, before benefits are credited to dilution flows, it is believed that all wastes should be treated to remove oils, greases, floating debris, and settleable solid materials. These materials inhibit reaer[illegible]ion, make the stream unsightly, and form sludge banks. Primary sewage treatment is usually successful in removing these materials.

The equivalent annual cost of sewage treatment facilities will vary according to the stream standards which are used as a basis for the computation. In the present case the stream quality criteria of the Interstate Commission on the Potomac River Basin have been used in calculating the total tangible benefits, since these criteria are the only comprehensive set of standards for stream water quality which have been established for the basin. In estimating the reimbursable benefits, however, it is necessary to use the same stream standards used by the agencies responsible for the reduction of pollution and to be guided by treatment regarded as necessary by them. In such cases it is possible to assign a reimbursable benefit only when it can be shown that flow augmentation will substitute completely for more thorough sewage treatment and that, consequently, needs for the type of treatment required may be altered due to the increase in flow provided. The Maryland Department of Health and the Maryland Water Pollution Control Commission regulate the discharge of sewage and of industrial wastes, respectively, into the waters of the State of Maryland. Their requirements for waste treatment in the area have been used in estimating reimbursable benefits.

When dilution of a stream improves its water quality so much that the water can then be used as an industrial or municipal supply, an additional monetary benefit credited to dilution can be the difference between the cost of using stream water and the cost of using water from the cheapest alternative source.

The North Branch receives massive industrial waste loads from three sources; of these, only the Fairfax Coal Washery would not be affected by augmented flows. Dilution would supplement waste treatment by the West Virginia Pulp and Paper Company and the Celanese Corporation.

The extensive waste treatment facilities planned by the West Virginia Pulp and Paper Company are expected to produce an effluent which will meet the minimum standards of the Maryland Water Pollution Control Commission except for color, which will probably not be greatly affected by the treatment.

Subsequent dilution of these wastes to meet the standards of the Interstate Commission for Class D streams would require a continuous minimum discharge of 1000 cfs at Luke, which is far beyond the capabilities of the proposed reservoirs. The value of the additional discharge which can be provided, however, will have a value which can be estimated as the annual cost of the sewage treatment facilities which would be necessary to obtain an equivalent reduction of oxygen-depleting substances.

Since the sewage of Luke, Piedmont, and Westernport probably will be treated by the paper mill's plant and form part of its discharge, the increased flow in the North Branch would have no additional effect on the abatement of pollution from those towns. The sewage discharge from Keyser, assuming primary treatment will be installed, will not be so great as to require any additional treatment.

The degrees of flow augmentation which the proposed reservoirs could develop together with reasonable degrees of treatment for the wastes discharged will not be sufficient to improve the water quality of the North Branch to such a degree that it could be treated economically to serve as a municipal water supply; the color would be too much to remove effectively by economical treatment means. In addition to this condition the Interstate Commission criteria on B.O.D. for streams suitable for municipal water supplies would not be met.

The next area downstream which might be affected by increased flow in the North Branch is the locality near the Celanese Plant. The plant management does not feel that changes in the North Branch would affect their operations in any way. Water treatment costs might be reduced very slightly, but not by a measureable amount. In the event of increasing production, any required waste treatment would be contingent upon the waste effluent characteristics and the requirements of the State of Maryland; not upon flow in the North Branch. Increased production would only result from changes in company operations and would not be affected by water supply.

The operations of the Kelly-Springfield Tire Company or the Potomac Edison Company would not be affected by increased flow in the North Branch. Existing water supplies are adequate for present operation and for any reasonable future expansion. Some slight reduction in maintenance costs might occur, but no such cost reduction can be estimated.

Since increased flow in the North Branch would not affect water use or current plans for waste treatment in this reach of the North Branch, a specific benefit to industries or municipalities cannot be assigned under existing instructions of Bureau of the Budget Circular No. A-47 on the estimation of benefits considered reimbursable by industries. The value of the decrease in pollution of the North Branch can be estimated, however, on the basis of the cost of sewage treatment facilities necessary to obtain an equivalent reduction of oxygen-depleting substances to meet the minimum stream quality criteria of the Interstate Commission. Such an estimate has been made and is based on the annual cost of additional secondary sewage treatment at the West Virginia Pulp and Paper Company, and at the Celanese Corporation Plant. Construction costs are amortized over a 25-year period at 4.5 per cent. These benefits plus those accruing in the Cumberland area are proportional to the degree of flow augmentation provided and are presented graphically in Figure 14.

Benefits to the Cumberland Area

The Cumberland water supply will not be affected by increased flow in the North Branch. Water from many smaller streams in the area could be treated at fairly low cost; North Branch water would require expensive treatment before it would be fit for municipal use. However, long range planning should consider a raw water supply from a Savage River impoundment.

Increased flow in the North Branch may have a decided effect on the degree of sewage treatment required for the Cumberland area in the future. At present primary treatment with chlorination is being installed. This will probably not be sufficient to bring the water quality of the

North Branch below Cumberland up to the Class D stream standards of the Interstate Commission at low-flow periods.

To maintain the Class D stream criteria below Cumberland on the basis of the Cumberland sewage load alone, intermediate or secondary treatment at Cumberland would be required for present flow conditions. Increased flows would permit a delay in construction of a secondary sewage treatment plant and a decrease in the amount of treatment necessary at a given time.

In estimating the treatment required at Cumberland it is assumed that after about 25 years the Cumberland sewage treatment facilities will be serving about 80,000 persons, and that after an additional 25 years the population served will be about 100,000.* Linear increases between these values were assumed. From this information and from information on the efficiency of primary sewage treatment plants, it is estimated that for flows at Cumberland equivalent to flows less than 270 cfs at Luke secondary sewage treatment would be required immediately to meet the minimum criteria of the Interstate Commission. For flows greater than 270 cfs at Luke some delay in construction could be permitted. For a discharge of 300 cfs at Luke about 5 years delay, and for a similar discharge of 400 cfs about 14 years delay could be allowed.

The benefits which would accrue at Cumberland are estimated from the average difference in annual cost between the secondary and primary

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* These estimates are based on population trends as analyzed by the Corps of Engineers and on information supplied by the City Engineer, Cumberland, Maryland.

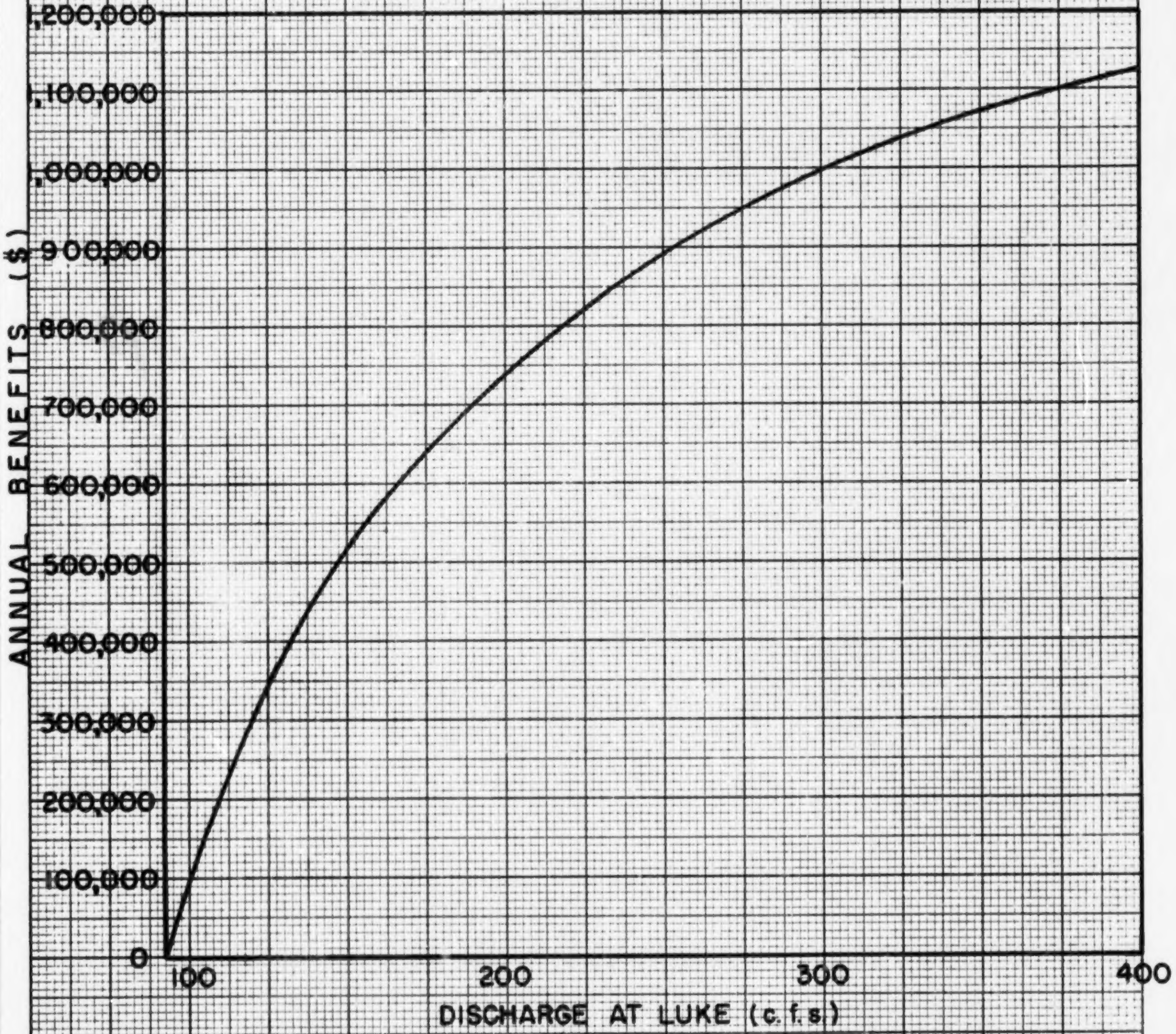

FIGURE 14. POLLUTION ABATEMENT BENEFITS FOR ADDITIONAL FLOW IN THE NORTH BRANCH POTOMAC RIVER

sewage treatment required during the life of the dam at various degrees of flow augmentation. Costs of construction are amortized for 25 years at 4.5 per cent. These benefits are summarized in Table 16, and are combined with the pollution abatement benefits from Celanese Corporation and the West Virginia Pulp and Paper Company to give the total pollution abatement benefits in Figure 14.

If it is assumed that the primary sewage treatment plant at Cumberland will reduce the sewage load enough to attain a water quality below Cumberland acceptable to the Maryland State Department of Health, then the benefits reimbursable by Cumberland according to Bureau of the Budget Circular A-47 can be estimated. In this case the benefits are calculated as the difference between the annual cost of a secondary sewage treatment plant and the annual cost of a primary treatment plant for the same sewage load. For each degree of flow augmentation considered here the number of years for which the primary sewage treatment plant would be adequate was estimated and the annual cost difference was prorated over 50-year amortization period of the dam. The benefits estimated in this manner are also included in Table 16, but are not included in Figure 14.

The operations of the Pittsburgh Plate Glass Company below Cumberland should not be affected by increased flow in the North Branch. The present water supply is adequate for a very large increase in water use and waste treatment facilities which should be capable of dealing with the waste from a large increase in production are being installed by the company.

TABLE 16

Pollution Abatement Benefits at Cumberland

North Branch Discharge at Luke (cfs)	Annual Benefits at Cumberland ($)	
	ICPR Criteria	Standards of Md. Dept. of Health
100	2,300	2,800
150	11,600	19,200
200	30,600	37,500
300	77,400	88,000
400	119,000	88,000

Economic Potential of Flow Augmentation

Provision of low-flow augmentation in the North Branch would encourage the expansion of industry into this valley, which is rich in other natural resources. The evaluation of this economic potential is not within the scope of this report. However, the Report to Maryland Water Pollution Control Commission on Proposed Expansion Program of West Virginia Pulp and Paper Company, Luke, Maryland, dated June 1, 1956 gives a clear picture as to the economic value of water to one industry, and an approximation of the value of the industry to the region. These figures were confidential and will not be reported here.

Intangible Benefits of Low-Flow Augmentation

There would be many effects of increased low-flow which would benefit the entire river valley. The over-all reduction in acid concentration above Luke and the greater dilution of industrial and municipal wastes would both result in an improvement in the water quality and the general appearance of the North Branch. Odor nuisances would be greatly reduced, and the dissolved oxygen content would be high enough to support fish and other forms of aquatic life in long reaches of the river. The improved water quality and quantity would probably result in increased industrial utilization of the river valley, with attendant increases in population and payrolls.

Increased flow in the North Branch in the reaches considered here would have a favorable effect in improving water quality downstream and in making it more suitable for storage in water supply reservoirs. While an increase of 200-300 cfs in minimum flow in the North Branch alone would have little effect on pollution abatement far downstream, as part of an over-all plan for low-flow augmentation in the Potomac River, increased flow in the North Branch would contribute its proportional part to pollution abatement in the Washington vicinity. The calculation of such benefits to the Washington area and other downstream areas must be deferred for a detailed study of conditions downstream of the region considered here.

Summary of Benefits

Table 17 presents the monetary benefits which may be expected from each of the three dams considered, assuming only one dam is built.

If more than one dam is constructed the benefits must be recalculated for each combination and a proportional distribution of the total benefits made according to the discharges and the effects of these discharges from each dam in the combination. This situation

TABLE 17

Annual Monetary Benefits from Augmentation of Minimum Continuous Flows in the North Branch Potomac River by Each Dam

Location of New Dam	Savage River above Present Dam	Stony River below U.S. Route 50	North Branch at Bloomington
Discharge from New Dam (cfs)	45	60	170-207
Total Tangible Benefits			
Benefits From			
1. Acid Reduction	$25,000	$23,000	$58,000-63,000
2. Temperature Reduction	$120,000	0	$246,000
3. Pollution Abatement(1)	$432,000	$530,000	$832,000-927,000
Total Tangible	$577,000	$553,000	$1,536,000-1,236,000
Total Tangible Benefits Reimbursable Under Bureau of Budget Circular A47			
Benefits From			
1. Acid Reduction	$25,000	$23,000	$58,000-63,000
2. Temperature Reduction	$62,000	0	$125,000
3. Pollution Abatement(2) (Equivalent Cumberland Sewage Treatment)	$16,000	$20,000	$52,500-79,000
Total Reimbursable Tangible	$103,000	$43,000	$235,500-267,000

(1) Calculated using Interstate Commission on the Potomac stream criteria.

(2) Calculated using Maryland Department of Health requirements.

results from several conditions:

(1) The differences in water quality in the reservoirs causes the water from each dam to have a different value in the reduction of acidity;

(2) The distance of each dam from the West Virginia Pulp and Paper Company affects the temperature reduction benefits attributable to it;

(3) The North Branch Dam operates by storing the low-flow-period discharge and replacing this discharge with water of more uniform chemical quality and temperature, thus having a different type of effect than the Savage River and Stony River Dams, which merely dilute the low-flow discharge of the North Branch;

(4) Each additional increment of diluting water has less value than the one which precedes it, as far as evaluating pollution abatement benefits is concerned. This can be seen graphically in Figure 15.

There are four combinations which should be considered. These are:

(1) Stony River and Savage River Dams,

(2) North Branch and Savage River Dams,

(3) North Branch and Stony River Dams,

(4) North Branch, Stony River, and Savage River Dams.

In each case it is assumed that the Savage River Dam will provide 45 cfs additional flows, the Stony River Dam will provide 60 cfs additional flow, and the North Branch will provide 170-207 cfs from the dam.

Since 36 cfs of this flow from the North Branch Dam must be assigned to maintain 93 cfs in combination with the present Savage River Dam (providing 57 cfs), this amounts to 134-171 cfs additional flow.

A combination of a Savage River Dam and a Stony River Dam providing 105 cfs augmentation would have an annual value of $902,000, of which $460,000 is assignable to the Savage River Dam and $442,000 is assignable to the Stony River Dam.

The distributions of benefits in the other three cases are shown graphically in Figures 15, 16, and 17.

Figure 15 shows the total benefits for each of the three combinations and for the North Branch Dam alone. For example, a dam on the North Branch capable of discharging a total of 190 cfs would provide an annual benefit of $1,190,000 if it were alone. If this dam were operated in conjunction with dams on both the Savage River and Stony River, the combination would provide an annual benefit of $1,427,000 for a total discharge of 352 cfs at Luke.

From Figure 16 the amount of the benefit assignable to the North Branch Dam for various combinations can be found. For the example just given, the annual benefit assignable to the North Branch Dam is $820,000.

From Figures 17a and 17b the amount of annual benefits assignable to the Stony River Dam and to the Savage River Dam, respectively, can be found for various combinations. For the example, the Stony River would have $347,000 per year benefits, and the Savage River would have $260,000 per year benefits.

The benefits for other combinations of the dams can be calculated

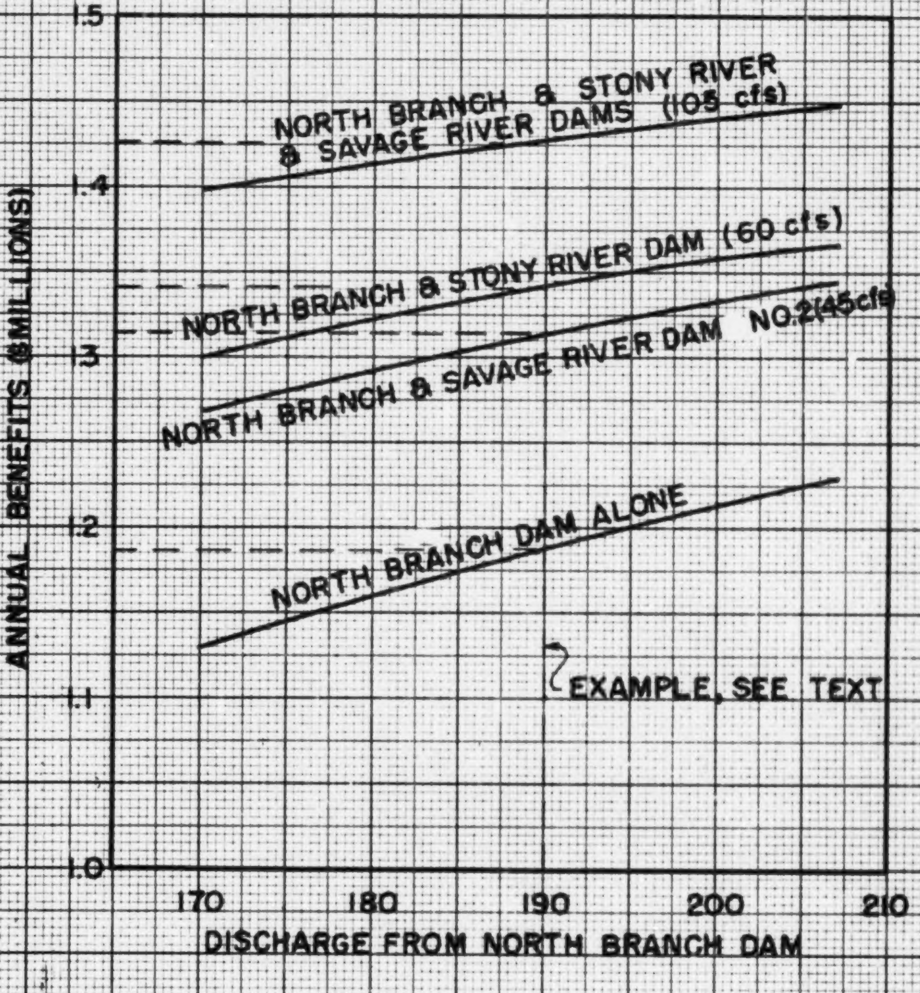

FIGURE 15. TOTAL ANNUAL BENEFITS FROM NORTH BRANCH DAM ALONE & IN COMBINATION WITH OTHER DAMS.

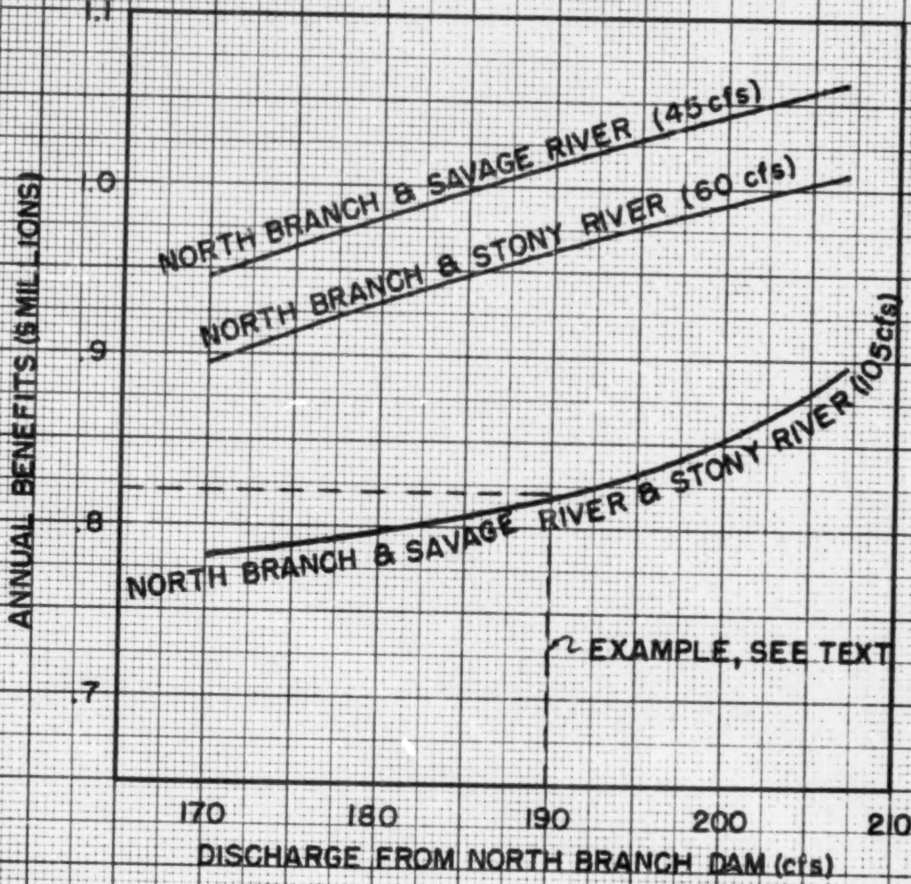

FIGURE 16. ANNUAL BENEFITS ASSIGNABLE TO NORTH BRANCH DAM WHEN IN COMBINATION WITH OTHER DAMS.

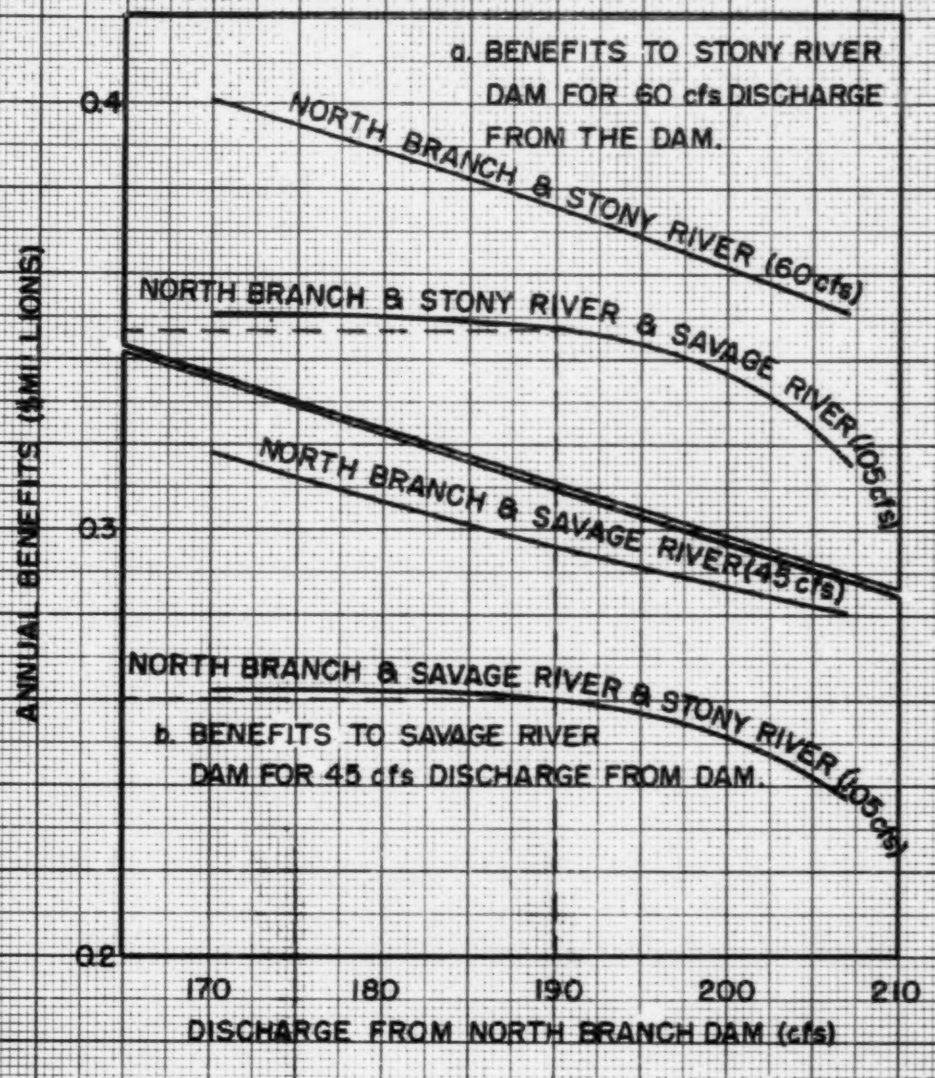

FIGURE 17 ANNUAL BENEFITS ASSIGNABLE TO SAVAGE RIVER DAM AND STONY RIVER DAM IN COMBINATION WITH VARIOUS DISCHARGES FROM NORTH BRANCH DAM.

similarly. The reimbursable tangible benefits for the several dam combinations can be calculated in the following manner:

(1) For a Stony River and Savage River Dam combination all the benefits are additive.

(2) For a Savage River and North Branch Dam combination, the pollution abatement and acid reduction benefits are additive, the total temperature reduction benefits for the combination will equal those for the North Branch alone.

(3) For a Stony River and North Branch Dam combination, the total pollution abatement benefits amount to $88,000 annually, and the acid reduction and temperature reduction benefits for the combination are equivalent to those for the North Branch Dam alone.

(4) For a combination of all three dams the total pollution abatement benefits amount to $88,000 annually, the temperature reduction benefits are equal to those from the North Branch Dam alone, and the acid reduction benefits are equal to the sum of those from the Savage River Dam and the North Branch Dam.

APPENDIX

TABLE A-1

INDIVIDUAL RESULTS OF SAMPLING OF THE NORTH BRANCH AND ITS TRIBUTARIES

Station	Date	Time	Temp (°C)	Discharge (cfs)	D.O. (ppm)	B.O.D. (ppm)	B.O.D. #/day	C.O.D. (ppm)	C.O.D. #/day	Solids (ppm)								Color (ppm)	pH	Alkalinity, ppm (Acidity, ppm)		Dissolved Fe (ppm)	Dissolved Fe++(ppm)	Dissolved Mn (ppm)	Tannin & Lignin (ppm)	Sulfate (ppm)
										Total (w/o Set.S.)	Settleable (p = 1.25)	Total Fixed	Total Volatile	Total Suspended	Total Suspended Fixed	Total Suspended Volatile	Total Dissolved			Phen. (M.O.)	Total (Total)					
1 - 1	9-18	8:05 A	12	4.5	7.46	0.22	5.3	-	-	-	3100	-	-	-	-	-	-	12	3.8	(27.0)	(56.0)	-	-	-	-	-
2	9-21	8:50 A	6	5.5	8.70	0	0	-	-	980	2500	240	740	-	-	-	-	95	3.7	(43.0)	(134.5)	-	-	-	-	-
3	9-24	9:00 A	13	4.6	6.47	1.0	25	-	-	-	7500	-	-	-	-	-	-	27	3.7	(28.5)	(84.0)	-	-	-	-	-
4	9-27	9:10 A	8	5.0	7.09	4.1	111	-	-	1280	3100	400	880	570	80	490	710	68	3.3	(66.0)	(376.0)	-	-	-	-	-
5	10-3	7:45 A	12	4.0	5.56	5.1	110	-	-	2600	6800	660	1940	2282	1083	1199	318	25	3.3	(66.5)	(145.5)	-	-	-	-	-
6	10-10	7:45 A	6	6.0	9.02	0.8	25.9	-	-	360	4600	120	240	11.2	3	8.2	349	47	3.6	(31.0)	(99.5)	-	-	-	-	-
7	10-18	8:10 A	9	4.2	5.40	3.2	72.6	-	-	3180	9800	420	2760	2749	1463	1286	431	38	3.7	(24.0)	(89.0)	-	-	-	-	-
8	10-23	7A→2:30P	-	4.0	-	-	-	-	-	2580	13500	650	1930	2445	1245	1200	135	-	-	-	-	-	-	-	-	-
2 - 1	9-18	8:00 A	13	(1)60	8.90	0.36	117	-	-	-	1000	-	-	-	-	-	-	5	3.7	(21.5)	(51.0)	-	-	-	-	-
2	9-21	8:45 A	6	(1)25	9.84	0	0	-	-	520	0	340	180	-	-	-	-	16	3.6	(46.5)	(121.5)	-	-	-	-	-
3	9-24	9:50 A	14	(1)32	8.88	0.3	52	-	-	-	-	-	-	-	-	-	-	16	3.4	(58.5)	(120.5)	-	-	-	-	-
4	9-27	9:05 A	9	(1)26	9.95	1.2	168	-	-	480	0	300	180	-	-	-	-	20	3.5	(57.5)	(116.5)	-	-	-	-	-
5	10-3	7:35 A	12	(1)15	8.80	0.3	24	-	-	620	0	380	240	6	2	4	614	14	3.2	(72.0)	(129.0)	-	-	-	-	-
6	10-10	8:00 A	6	(1)49	10.24	0.41	108	-	-	140	0	40	100	4.7	0	4.7	135	10	3.8	(18.0)	(51.5)	-	-	-	-	-
7	10-18	8:00 A	9	(1)26	9.83	0.66	92	-	-	340	0	100	240	10	4	6	330	24	3.1	(55.0)	(120.0)	-	-	-	-	-
3 - 1	9-18	8:20 A	12	(1)66	8.69	0.22	78.4	-	-	-	1100	-	-	-	-	-	-	5	3.7	(20.5)	(52.0)	-	-	-	-	-
2	9-21	8:30 A	6	(1)30	9.85	0.1	16.2	-	-	480	0	280	200	-	-	-	-	17	3.7	(40.5)	(111.5)	-	-	-	-	-
3	9-24	8:40 A	14	(1)37	8.24	0.9	180	-	-	-	-	-	-	-	-	-	-	15	3.4	(56.0)	(114.0)	-	-	-	-	-
4	9-27	8:55 A	9	(1)31	9.41	1.3	218	-	-	460	0	260	200	-	-	-	-	21	3.5	(58.5)	(119.0)	-	-	-	-	-
5	10-3	7:15 A	13	(1)24	7.95	0.1	13.0	-	-	560	0	360	200	14	7	7	546	24	3.5	(47.0)	(110.5)	-	-	-	-	-
6	10-10	7:35 A	6	(1)54	9.89	0.02	5.83	-	-	140	0	40	100	16.1	.7	15.4	124	39	3.9	(11.5)	(49.0)	-	-	-	-	-
7	10-18	7:45 A	10	(1)30	9.40	0.65	105	-	-	300	0	80	220	33.5	7.4	26.1	266	14	3.2	(49.0)	(95.0)	-	-	-	-	-
4 - 1	9-18	8:35 A	13	(2)1.6	9.48	1.08	9.4	-	-	-	0	-	-	-	-	-	-	37	7.5	-	10.9	0.40	-	0.24	-	-
2	9-21	9:15 A	7	(2)1.6	10.25	0.90	7.8	-	-	220	0	140	80	-	-	-	-	34	6.0	-	10.5	0.58	0.04	0.09	-	-
3	9-24	9:20 A	14	(2)26	8.66	0.70	98	-	-	-	-	-	-	-	-	-	-	48	7.5	-	9.5	0.84	0.07	0.17	-	-
4	9-27	9:35 A	8	(2)26	9.68	0.60	84	-	-	100	0	60	40	21	11	10	79	50	5.9	-	9.0	1.46	0.14	0.16	-	-
5	10-3	8:30 A	14	(2)26	8.88	0.5	70	-	-	240	0	200	40	11.6	2.4	9.2	228	45	7.2	-	9.5	0.75	-	0	-	0.81
6	10-10	8:15 A	8	(2)150	9.94	1.46	1200	-	-	160	0	60	100	11.4	4.0	7.4	149	47	4.5	(-)	(11.0)	-	-	-	-	2.2
7	10-18	8:30 A	10	(2)10	9.46	0.43	23	-	-	40	0	20	20	21.4	10.7	10.7	19	33	6.6	-	7.5	-	-	-	-	0.64
5 - 1	9-18	9:10 A	14	196	8.97	0.36	381	-	-	-	400	-	-	-	-	-	-	4	3.9	(10.5)	(52.0)	0.62	-	0.64	-	-
2	9-21	7:45 A	8	90	10.16	0.8	389	-	-	280	0	220	60	-	-	-	-	3	4.5	-	(25.0)	0.95	0.12	0.70	-	-
3	9-24	7:45 A	15	128	8.82	0.60	415	-	-	-	-	-	-	-	-	-	-	6	4.5	-	19.5	0.88	0.03	0.43	-	-
4	9-27	8:00 A	10	120	9.66	1.4	907	-	-	200	0	120	80	-	-	-	-	10	4.5	-	7.0	0.97	0.12	0.47	-	-
5	10-3	6:35 A	12	110	9.11	0.8	475	-	-	280	0	220	60	3.6	0.8	2.4	276	7	4.3	(1.5)	(20.5)	0.94	-	0.47	-	-
6	10-10	6:45 A	9	318	10.25	0.86	1480	-	-	40	0	0	40	5.4	2.0	3.4	35	14	4.9	-	8.5	0.52	-	0.48	-	2.8
7	10-18	7:00 A	10	122	9.60	0.63	415	-	-	80	0	40	40	6.0	1.6	4.4	74	4	4.3	(3.5)	(18.0)	0.19	-	0.31	-	5.7
6 - 1	9-18	9:50 A	16	195	9.23	0.90	948	-	-	-	0	-	-	-	-	-	-	6	3.8	(10.5)	(37.0)	0.49	-	0.88	-	-
2	9-21	10:10 A	11	89	10.29	0.6	288	-	-	300	0	260	40	-	-	-	-	8	4.05	(8.0)	(34.0)	1.41	0.23	0.78	-	-
3	9-24	11:25 A	18	117	8.99	0.20	126	-	-	-	-	-	-	-	-	-	-	0	4.0	(8.5)	(38.0)	1.17	0.08	0.88	-	-
4	9-27	11:40 A	12	113	9.91	2.7	1648	-	-	280	0	220	60	14	9	5	260	4	4.2	(11.5)	(38.5)	1.52	0.26	0.76	-	-
5	10-3	10:45 A	17	111	9.08	1.3	779	-	-	300	0	260	40	4.4	1.6	2.8	296	8	4.2	(5.0)	(29.0)	1.19	-	1.0	-	-
6	10-10	10:50 A	12	392	10.11	0.77	1630	-	-	100	0	40	60	9.4	5.4	4.0	91	11	4.6	-	6.0	1.30	-	0.69	-	-
7	10-18	11:05 A	14	132	9.29	2.01	1433	-	-	140	0	80	60	6.8	3.2	3.6	133	2	4.2	(6.0)	(25.0)	0.08	-	0.13	-	-

(1) Estimated from Discharges at Steyer (Gage recently installed by U.S.G.S.)
(2) Discharges from Stony River Dam.

TABLE A-1

INDIVIDUAL RESULTS OF SAMPLING OF THE NORTH BRANCH AND ITS TRIBUTARIES

Station	Date	Time	Temp (°C)	Discharge (cfs)	D.O. (ppm)	B.O.D. (ppm)	B.O.D. #/day	C.O.D. (ppm)	C.O.D. #/day	Solids (ppm)								Color (ppm)	pH	Alkalinity, ppm (Acidity, ppm)		Dissolved Fe (ppm)	Dissolved Fe++ (ppm)	Dissolved Mn (ppm)	Tannin & Lignin (ppm)	Sulfate (ppm)
										Total (w/o Set.S.)	Settleable (p = 1.25)	Total Fixed	Total Volatile	Total Suspended	Total Suspended Fixed	Total Suspended Volatile	Total Dissolved			Phen. (M.O.)	Total (Total)					
7 - 1	9-18	9:55 A	11	121	10.46	0.62	405	-	-	-	0	-	-	-	-	-	-	6	7.3	-	13.0	0.07	-	0.13	-	-
2	9-21	11:25 A	11	121	10.40	0.9	588	-	-	180	0	140	40	-	-	-	-	20	8.7	2.0	22.0	0.16	0.02	0.08	-	-
3	9-24	11:30 A	14	119	9.73	1.0	643	-	-	-	-	-	-	-	-	-	-	12	7.4	-	17.0	0.19	0	0.18	-	-
4	9-27	11:45 A	12	119	10.03	0.6	386	-	-	100	0	60	40	3.2	2.0	1.2	97	13	6.5	-	18.0	0.22	0.04	0.12	-	-
5	10-3	10:45 A	16	117	9.26	1.6	101	-	-	220	0	140	80	7.2	1.2	6.0	213	15	8.0	-	18.0	0.51	-	0.27	-	-
6	10-10	11:05 A	14	116	9.88	0.74	464	-	-	40	0	0	40	6.0	0	6.0	34	18	6.9	-	18.5	0.21	-	0.45	-	-
7	10-18	11:05 A	14	114	9.58	0.5	308	-	-	60	0	20	40	11.2	7.6	3.6	49	11	7.3	-	18.5	-	-	0.08	-	-
8 - 1	9-18	10:35 A	13	14	9.71	1.02	77.1	-	-	-	0	-	-	-	-	-	-	10	7.2	3.5	15.5	0.07	-	-	-	-
2	9-21	10:50 A	8	10	10.82	0.7	37.8	-	-	100	0	60	40	-	-	-	-	23	6.6	-	20.0	0.15	0.06	0.07	-	-
3	9-24	10:50 A	15	11	9.47	0.8	47.5	-	-	-	-	-	-	-	-	-	-	17	7.1	-	18.5	0.08	0.02	0.26	-	-
4	9-27	11:00 A	10	7.7	10.16	0.5	20.8	-	-	180	0	40	140	7.2	4.8	2.4	173	10	6.4	-	21.5	0.07	0.04	0.37	-	-
5	10-3	10:00 A	14	6.2	9.51	0.4	13.4	-	-	140	0	140	0	8.8	2.0	6.8	131	10	6.8	-	20.5	0.08	-	0	-	-
6	10-10	10:15 A	8	21	11.01	0.4	45.4	-	-	20	0	0	20	.7	0	.7	19.3	18	7.0	-	18.5	-	-	-	-	-
7	10-18	10:15 A	11	14	10.04	0.4	30.2	-	-	20	0	0	20	2.4	1.6	.8	18	8	7.2	-	18.5	-	-	-	-	-
6 - 01	9-19	8:35 A	14	153	9.48	0.77	636	8.23	6800	-	-	-	-	-	-	-	-	0	4.3	(4.0)	(26.3)	-	-	-	0.2	-
02	9-25	9:10 A	14	141	9.35	1.0	761	10.1	7690	-	-	-	-	-	-	-	-	1	4.1	(0.6)	(31.0)	-	-	-	0.2	9.4
03	10-1	8:20 A	14	143	9.20	0.6	463	9.64	7440	-	-	-	-	-	-	-	-	0	4.2	(3.5)	(23.0)	-	-	-	0.75	4.8(?)
04	10-4	8:10 A	17	228	8.27	0.4	493	7.3	8990	420	0	280	140	19.3	7.3	12.0	401	2	4.0	(10.0)	(38.0)	-	-	-	0.3	11.4
05	10-8	6:35 A	10	618	9.91	0.5	1670	26.6	88800	120	0	20	100	21.4	10.7	10.7	99	6	4.6	-	(13.0)5.0	1.99	-	0.62	0.8	4.3
06	10-11	9:45 A	8	356	9.36	0.55	1060	7.80	15000	100	0	60	40	9.2	2.8	6.4	94	8	4.6	-	(14.0)6.5	-	-	-	0.35	4.7
07	10-15	7:10 A	10	271	9.90	0.9	1320	7.41	10800	100	0	60	40	6.9	1.2	5.6	93	3	4.5	-	(16.5)4.5	0.99	-	0.45	0.2	5.3
7 - 01	9-19	8:45 A	10	121	10.40	1.02	667	5.10	3330	-	-	-	-	-	-	-	-	7	7.9	-	14.5	-	-	-	0.25	-
02	9-25	9:00 A	12	119	10.05	1.1	707	3.88	2490	-	-	-	-	-	-	-	-	14	7.8	-	20.5	-	-	-	0.25	0.18
03	10-1	8:30 A	13	117	9.71	1.2	758	5.02	3170	-	-	-	-	-	-	-	-	13	7.5	-	20.5	-	-	-	0.50	-
04	10-4	8:30 A	15	117	8.92	1.0	632	13.5	8530	200	0	180	20	35.5	20.1	15.4	164	14	6.5	-	15.5	-	-	-	0.45	-
05	10-8	6:45 A	11	116	9.71	0.1	62.6	3.98	2490	60	0	0	60	4.8	0	2.4	55	12	7.0	-	18.0	-	-	-	0.3	1.2
06	10-11	9:00 A	11	116	10.22	0.6	376	5.85	3660	60	0	40	20	7.2	2.4	7.2	53	14	7.0	-	21.5	-	-	-	0.3	1.4
07	10-15	7:20 A	12	114	9.73	0.7	431	4.29	2640	80	0	40	40	7.6	2.0	5.6	72	10	7.3	-	20.0	-	-	-	0.3	1.4
9 - 1	9-19	8:20 A	16	274	2.10	18.9	28000	87.8	130000	320	6000	280	40	-	-	-	-	18	10.5	58.0	122.0	-	-	-	5.5	-
2	9-25	8:50 A	17	260	5.96	30.3	42500	140.8	198000	360	0	140	220	76.8	20.4	56.4	283	204	5.8	-	17.0	-	-	-	8.6	8.6
3	10-1	8:45 A	17	260	6.40	23.6	33100	103.9	146000	500	3000	100	400	60.3	10.1	50.2	440	99	5.0	-	7.0	-	-	-	8.5	8.4
4	10-4	8:40 A	20	345	6.90	26.0	48400	125.8	234000	660	0	400	260	170	88	82	490	93	9.6	17.0	138.0	-	-	-	3.5	7.1
5	10-8	7:15 A	11	734	9.15	5.6	22200	37.3	148000	140	0	40	100	34.2	14.7	19.5	106	32	6.3	-	9.0	-	-	-	1.7	4.1
6	10-11	7:45 A	10	472	9.28	20.0	51000	53.8	137000	180	0	20	160	51.6	16.8	34.8	128	49	6.8	-	21.0	-	-	-	1.6	4.5
7	10-15	6:45 A	14	385	8.25	15.5	32300	70.6	147000	180	0	140	40	54.3	19.4	34.9	126	63	6.9	-	18.0	-	-	-	2.7	4.9
8	10-18	4:30 P	20	246	-	36.8	48900	165.6	220000	340	0	120	220	75.7	22.8	52.9	264	250	7.6	-	38.5	0.95	-	0.46	12.5	6.6
10 - 1	9-19	8:55 A	11	20	9.92	6.4	691	10.6	1150	600	300	530	70	-	-	-	-	1	4.3	(5.0)	(36.0)	-	-	-	1.5	-
2	9-25	9:55 A	12	15	9.80	1.3	105	10.5	851	740	0	560	180	9.6	5.6	4.0	730	5	4.0	(8.0)	(47.0)	-	-	-	0.8	45.3
3	10-1	8:00 A	12	15	9.58	3.6	292	11.6	940	720	0	560	160	14.4	2.8	11.6	706	5	4.3	(3.5)	(39.0)	-	-	-	1.6	45.6
4	10-4	7:35 A	16	60	8.51	2.3	497	61.4	13300	1340	0	920	420	283	225	58	1057	20	3.7	(29.5)	(94.0)	-	-	-	0.7	52.7
5	10-8	6:20 A	9	29	10.31	1.0	157	7.94	12400	400	0	240	160	10.7	4.7	6.0	389	1	4.7	-	6.0	-	-	-	0.7	27.8
6	10-11	8:35 A	8	19	10.11	2.3	236	8.97	9200	540	0	280	260	12.7	3.4	9.3	527	8	4.9	-	10.0	-	-	-	0.6	33.9
7	10-15	6:55 A	10	16	10.13	0.8	69.1	7.80	6740	720	0	480	240	12.1	3.4	8.7	708	2	4.3	(5.0)	(43.0)	-	-	-	0.2	40.3
10A- 1	9-19	9:15 A	10	16	9.62	7.1	613	-	-	-	-	-	-	-	-	-	-	2	7.8	-	15.0	-	-	-	-	-
2	9-25	9:30 A	11	11	9.88	0.5	30	-	-	-	-	-	-	-	-	-	-	5	7.6	-	15.5	-	-	-	-	-
3	10-1	7:40 A	11	11	9.64	1.0	59	-	-	580	0	440	140	11.2	4.0	7.2	569	1	6.7	-	20.0	-	-	-	-	35.5
4	10-4	7:15 A	15	35	8.50	4.7	890	-	-	660	0	520	140	109	67	42	551	9	6.4	-	20.5	-	-	-	-	26.4
5	10-10	11:30 A	10	25	10.16	1.6	216	4.36	589	420	0	280	140	6.7	1.3	5.4	413	17	6.7	-	18.5	-	-	-	-	25.3
6	10-11	8:00 A	8	15	11.11	1.6	130	3.51	284	460	0	260	200	20.8	7.3	13.5	439	9	6.6	-	19.5	-	-	-	-	26.5
7	10-18	11:30 A	14	12	9.11	0.6	39	12.9	836	520	0	280	240	15.2	9.6	14.6	505	5	6.7	-	14.0	0.37	-	-	-	32.5

TABLE A-1

INDIVIDUAL RESULTS OF SAMPLING OF THE NORTH BRANCH AND ITS TRIBUTARIES

Station	Date	Time	Temp (°C)	Discharge (cfs)	D.O. (ppm)	B.O.D. (ppm)	B.O.D. #/day	C.O.D. (ppm)	C.O.D. #/day	Solids (ppm)								Color (ppm)	pH	Alkalinity, ppm (Acidity, ppm)		Dissolved Fe (ppm)	Dissolved Fe++(ppm)	Dissolved Mn (ppm)	Tannin & Lignin (ppm)	Sulfate (ppm)
										Total (w/o Set.S.)	Settleable (p = 1.25)	Total Fixed	Total Volatile	Total Suspended	Total Suspended Fixed	Total Suspended Volatile	Total Dissolved			Phen. (M.O.)	Total (Total)					
11 - 1	9-19	7:50 A	12	11	9.22	1.64	97.4	5.49	326	-	-	-	-	-	-	-	-	6	8.0	-	91.5	-	-	-	-	-
2	9-25	7:20 A	12	6.3	9.36	1.1	37.4	12.03	409	-	-	-	-	-	-	-	-	9	7.8	-	104.5	-	-	-	-	-
3	10-1	6:55 A	12	8.4	8.66	1.4	63.5	5.02	228	180	0	80	100	12.8	4.8	8.0	167	7	8.0	-	103.5	-	-	-	-	-
4	10-4	6:30 A	16	32	6.74	3.2	553	19.3	3340	440	0	320	120	102.5	85.8	16.7	337	32	7.3	-	88.0	-	-	-	-	-
5	10-10	9:10 A	9	16	11.60	0.54	46.7	1.6	138	140	0	60	80	3.6	1.6	2.0	136	10	-	-	-	-	-	-	-	-
6	10-11	9:30 A	7	14	12.45	1.6	121	5.46	413	160	0	20	140	10.8	5.2	5.6	149	9	7.8	-	91.5	-	-	-	-	-
7	10-18	6:15 A	12	9.2	8.21	1.4	69.6	1.96	97.4	180	0	20	160	6.8	6.4	0.4	173	9	7.8	-	100.0	-	-	-	-	-
12 - 1	9-19	8:05 A	14	*305	7.25	16.7	27500	61.5	101000	240	2500	140	100	-	-	-	-	40	7.7	-	16.0	0.69	-	0.46	3.6	-
2	9-25	7:30 A	16	297	5.86	20.1	32200	108.3	174000	320	0	180	140	78.8	18.8	60.0	241	102	6.5	-	23.0	0.89	0.34t	0.58	6.1	-
3	10-1	7:05 A	16	297	4.82	15.5	24900	66.4	106000	280	2800	160	120	35.2	8.4	26.8	245	108	7.1	-	33.0	0.85	-	2.28(?)	9+	-
4	10-4	6:50 A	20	408	2.40	3.1	6800	117.7	259000	980	0	400	180	82.4	33.5	48.9	498	122	9.2	13.0	99.5	0.68	-	0.42	5.9	-
5	10-8	6:00 A	12	809	8.37	12.3	53700	48.0	210000	180	0	40	140	60.3	24.1	36.2	120	46	6.9	-	18.5	-	-	-	1.9	-
6	10-11	7:30 A	10	520	7.50	24.1	67700	58.9	165000	220	0	40	180	41.5	12.7	28.8	178	94	7.3	-	41.5	-	-	-	2.3	-
7	10-15	6:25 A	13	425	7.55	11.5	26400	59.7	137000	220	0	120	100	36.2	14.1	22.1	184	78	7.2	-	23.0	-	-	-	3.3	-
13 - 1	9-19	9:50 A	15	*337	6.97	17.8	32400	35.6	64800	-	2500	-	-	-	-	-	-	35	7.7	-	18.5	-	-	-	-	-
2	9-25	10:15 A	16	328	5.56	19.3	34200	71.0	126000	280	0	80	200	-	-	-	-	78	6.6	-	26.0	-	-	-	-	-
3	10-1	10:20 A	18	328	5.47	13.4	23700	78.6	139000	280	4200	160	120	46.2	12.1	34.1	234	110	6.7	-	29.0	-	-	-	-	-
4	10-4	9:00 A	19	451	5.03	9.2	22400	99.0	144000	420	0	260	160	21.4	5.9	15.5	399	128	6.9	-	44.0	-	-	-	-	-
5	10-8	7:35 A	12	893	8.50	7.2	34700	42.1	203000	180	0	80	100	52.3	23.5	28.8	128	47	6.8	-	-	-	-	-	-	-
6	10-11	10:00 A	12	574	8.03	17.9	55500	68.6	213000	220	0	120	100	48.9	13.4	35.5	171	100	7.3	-	36.0	-	-	-	-	-
7	10-15	7:50 A	13	469	7.60	9.0	22800	49.1	124000	220	0	100	120	31.5	11.4	20.1	188	64	7.1	-	25.5	-	-	-	-	-
14 - 1	9-19	10:20 A	16	*363	5.14	10.9	21400	56.8	111000	160	0	160	0	-	-	-	-	70	7.7	-	49.0	1.0	-	0.34	3.9	-
2	9-25	10:45 A	18	259	5.56	6.1	8530	43.5	60800	300	0	140	160	62.8	15.6	47.2	237	105	6.8	-	39.0	1.52	0.28	0.81	3.8	-
3	10-1	9:45 A	16	300	6.00	8.5	13800	30.9	50100	240	0	140	100	3.6	1.2	2.4	236	76	7.1	-	36.5	1.03	-	0.57	3.1	-
4	10-4	9:30 A	20	322	5.01	9.3	16200	43.2	75100	340	0	180	160	20.8	8.7	12.1	319	122	7.0	-	46.0	1.40	-	0.72	5.4	-
5	10-8	8:15 A	12	940	7.20	6.6	33500	56.0	284000	200	0	120	80	97.8	56.3	41.5	102	42	7.0	-	29.5	0.96	-	0.49	1.8	-
6	10-11	10:30 A	12	540	8.10	11.5	33900	49.5	144000	80	0	20	60	39.5	18.1	21.4	40	77	7.2	-	33.5	-	-	-	2.3	-
7	10-15	8:30 A	14	457	6.35	5.9	14600	38.6	95300	280	0	180	100	25.5	9.4	16.1	254	60	7.2	-	36.5	0.77	-	0.49	2.1	-
01	9-20	7:20 A	16	279	6.68	3.9	5890	40.7	61300	200	0	160	40	-	-	-	-	61	7.0	-	31.2	-	-	-	-	-
02	9-26	7:40 A	16	263	6.17	5.6	7950	35.1	49900	240	0	200	40	25.6	13.2	12.4	214	98	7.1	-	36.0	-	-	-	-	-
03	10-2	7:30 A	16	275	5.69	4.3	6390	39.3	58400	140	0	140	0	18.1	6.7	11.4	122	96	7.0	-	35.5	-	-	-	-	-
16 - 1	9-20	7:40 A	18	*282	5.68	12.7	19300	29.4	44800	300	0	240	60	-	-	-	-	74	6.3	-	37.0	-	-	-	-	-
2	9-26	8:05 A	18	266	4.60	12.0	17200	38.6	55400	260	0	220	40	10.0	4.8	5.2	250	106	7.0	-	47.0	-	-	-	-	-
3	10-2	7:45 A	17	278	6.24	3.5	5300	28.6	42900	340	0	340	0	42.9	29.5	13.4	297	58	7.1	-	47.5	-	-	-	-	-
4	10-8	8:30 A	13	945	7.06	6.6	33700	66.7	340700	240	0	120	120	97.2	52.9	44.3	143	44	6.9	-	24.0	-	-	-	-	-
5	10-15	10:20 A	16	460	6.90	20.6	51200	70.2	174000	220	0	180	40	34.8	14.7	20.1	185	63	6.4	-	29.5	-	-	-	-	-
17 - 1	9-20	10:25 A	14	114	9.47	3.7	2280	34.1	21000	360	0	300	60	-	-	-	-	20	6.7	-	43.0	0.02	0.01	0.44	0.18	-
2	9-26	8:35 A	13	73	8.93	4.1	1620	8.1	3190	240	0	200	40	20.0	16.0	4.0	220	11	7.4	-	45.5	0.32	0.06	0.60	0.5	-
3	10-2	8:35 A	14	58	8.83	7.5	2350	22.4	7020	440	0	440	0	221.1	201.7	20.0	199	21	7.0	-	43.5	-	-	-	neg.0	-
4	10-10	12:15 P	12	114	10.97	3.2	1970	7.54	4640	260	0	140	120	74.4	62.3	12.1	186	20	-	-	-	-	-	-	-	-
5	10-18	12:30 P	15	66	11.34	8.1	2890	9.40	3350	260	0	200	60	20.0	12.4	7.6	240	11	7.6	-	38.5	-	-	-	-	-
18 - 1	9-20	8:10 A	18	**292	2.77	13.7	21600	53.3	84000	-	-	-	-	-	-	-	-	49	6.6	-	47.0	1.40	0.23	0.66	3.85	-
2	9-26	8:25 A	20	263	0.62	9.0	12800	38.4	54900	280	0	220	60	-	-	-	-	109	7.1	-	52.5	1.66	0.25	0.81	4.3	-
3	10-2	8:20 A	18	278	1.85	4.5	6800	32.8	49200	180	0	180	0	16.8	4.0	12.8	163	66	6.9	-	47.0	1.25	-	0.83	2.9	-
4	10-8	1:00 P	15	1082	6.26	5.2	30400	26.6	155400	280	0	240	40	30.8	18.8	12.0	249	57	6.8	-	-	-	-	-	1.5	-
5	10-15	8:55 A	14	465	4.90	5.4	13600	37.1	93200	200	0	120	80	20.1	6.0	14.1	180	62	7.1	-	39.0	-	-	-	2.0	-

*Estimated from Gages at Luke, Pinto, and Keyser (on New Creek)

**Estimated from Gages at Wileys Ford and on Wills Creek

TABLE A-1

INDIVIDUAL RESULTS OF SAMPLING OF THE NORTH BRANCH AND ITS TRIBUTARIES

Station	Date	Time	Temp (°C)	Discharge (cfs)	D.O. (ppm)	B.O.D. (ppm)	B.O.D. #/day	C.O.D. (ppm)	C.O.D. #/day	Solids (ppm)								Color (ppm)	pH	Alkalinity, ppm (Acidity, ppm)		Dissolved Fe (ppm)	Dissolved Fe++(ppm)	Dissolved Mn (ppm)	Tannin & Lignin (ppm)	Sulfate (ppm)
										Total (w/o Set.S.)	Settleable (p = 1.25)	Total Fixed	Total Volatile	Total Suspended	Total Suspended Fixed	Total Suspended Volatile	Total Dissolved			Phen. (M.O.)	Total (Total)					
19 - 1	9-20	8:30 A	17	406	6.90	4.3	9430	55.6	122000	280	0	180	100	-	-	-	-	70	6.4	-	50.0	-	-	-	-	-
2	9-26	8:55 A	18	336	6.07	5.5	9980	34.4	62400	340	0	240	100	42.0	32.5	9.5	298	93	7.1	-	51.0	-	-	-	-	-
3	10-2	9:00 A	18	336	6.10	3.3	5990	28.6	51900	240	0	220	20	50.9	38.9	12.0	189	59	7.1	-	48.0	-	-	-	-	-
4	10-8	9:45 A	14	1220	7.65	5.0	32900	25.0	165000	120	0	0	120	43.8	34.2	9.6	76	56	7.0	-	-	-	-	-	-	-
5	10-15	10:00 A	14	541	7.58	4.9	14300	31.2	91200	200	0	200	0	24.8	18.8	6.0	175	55	7.2	-	43.0	-	-	-	-	-
20 - 1	9-20	9:15 A	14	(3)13	8.78	0.9	63	18.42	1300	-	-	-	-	-	-	-	-	23	6.7	-	98.0	-	-	-	-	-
2	9-26	9:30 A	14	(3)13	8.75	1.2	84	18.1	1300	240	0	220	20	111.9	101.2	11	128	35	7.75	-	105.0	-	-	-	-	-
3	10-2	9:45 A	14	(3)13	9.10	1.1	77	8.1	570	120	0	100	20	10.4	5.6	4.8	110	12	7.8	-	107.5	-	-	-	-	-
4	10-10	1:50 P	12	(3)15	11.94	0.91	74	1.6	130	220	0	140	80	8.7	3.4	5.3	211	15	-	-	-	-	-	-	-	-
5	10-18	12:50 P	17	(3)14	10.90	1.3	98	5.48	410	140	0	100	40	12.0	8.0	4.0	128	14	8.0	-	111.5	-	-	-	-	-
21 - 1	9-20	8:45 A	18	430	4.97	4.5	10500	43.9	102000	440	0	340	100	-	-	-	-	78	6.4	-	50.5	1.02	0.18	0.72	2.5	-
2	9-26	9:10 A	18	358	3.62	5.6	10800	31.3	60500	280	0	220	60	33	25	8	247	102	7.45	-	61.0	1.60	0.38	0.70	4.1	-
3	10-2	9:20 A	18	358	4.19	3.6	7000	32.0	62000	280	0	240	40	39.5	28.8	10.7	240	62	7.1	-	49.5	1.11	-	0.86	2.8	-
4	10-8	10:00 A	14	1290	6.84	4.2	29300	26.6	185000	180	0	160	20	44.9	30.2	14.7	135	64	7.1	-	-	-	-	0.62	1.8	-
5	10-15	10:15 A	14	560	7.40	3.6	10900	32.4	98000	180	0	180	0	20.8	14.1	6.7	159	64	7.1	-	44.5	-	-	0.62	1.6	-
22 - 1	9-22	10:00 A	16	(4)487	6.80	2.5	6570	28.7	75500	300	0	220	80	-	-	-	-	41	6.9	-	54.5	0.78	0.15	0.30	1.35	-
2	9-26	9:55 A	17	(4)454	6.14	2.6	6370	27.4	67200	320	0	160	160	20.4	18.4	2.0	300	61	7.0	-	57.0	1.11	0.18	0.44	1.85	-
3	10-2	10:20 A	16	(4)510	6.75	2.0	5510	18.9	52100	260	0	220	40	14.7	6.7	8.0	245	47	7.2	-	48.0	0.89	-	0.43	1.9	-
4	10-8	10:40 A	15	(4)1480	6.87	3.3	26300	23.8	190000	240	0	200	40	51.6	34.9	16.7	188	53	7.2	-	-	-	-	-	1.5	-
5	10-15	11:55 A	14	(4)709	6.85	2.3	8800	22.6	86500	180	0	180	0	10.1	8.0	2.1	170	54	7.5	-	52.5	-	-	-	1.4	-
23 - 1	9-26	10:25 A	16	654	7.69	0.9	3180	15.8	55800	260	0	180	80	21.6	20.4	1.2	238	40	7.2	-	65.5	0.74	0.08	0.25	1.05	-
2	10-2	11:05 A	16	763	7.80	1.5	6180	17.8	73300	220	0	180	40	14.7	7.4	7.3	205	42	7.5	-	60.0	0.69	-	0.50	1.6	-
3	10-8	11:10 A	16	1800	7.91	1.8	17500	15.5	151000	160	0	60	100	30.2	20.8	9.4	130	35	7.2	-	46.0	0.52	-	0.84	0.75	-
4	10-15	11:30 A	14	905	8.30	1.5	7330	12.5	61100	160	0	160.	0	8.7	8.0	0.7	151	41	7.4	-	50.0	0.53	-	0.24	0.75	-
33-24-1	10/16-10/17	1 hr.	-	6.8	-	123.5	4530	-		610	-	240	370	169	31	138	441	88	7.5	-	157.5	-	-	-	-	-
33-24-2	10/17-10/18	1 hr.	-	6.7	-	122.5	4430	-		440	2800	50	390	118	13	105	322	78	7.3	-	160	-	-	-	-	-
6-24-1	10/10-10/11	2 hrs.	-	354	8.82	0.96	1840	6.24	11900	140	0	80	60	9.2	4.8	4.4	131	10	4.5	-	6.5	0.20	-	0.32	0.2	4.79
6-24-2	10/15-10/16	2 hrs.	-	246	-	0.57	798	3.92	5220	140	0	120	20	26.1	7.3	18.8	114	4	3.9	(6.5)	(20.5)	0.86	-	0.40	0.3	5.38
6-24-3	10/18-10/19	2 hrs.	-	136	-	0.40	293	1.96	1440	120	0	20	100	0	0	0	120	3	4.1	(5.5)	(27.5)	0.19	-	0.54	0.15	8.10
7-24-1	10/10-10/11	2 hrs.	-	116	8.94	0.67	420	4.29	2690	80	0	40	40	6.0	2.8	3.2	74	16	6.9	-	20.5	0.13	-	0.04	0.3	1.35
7-24-2	10/15-10/16	2 hrs.	-	114	-	0.47	290	5.88	3620	100	0	60	40	12.1	0.7	11.4	88	11	7.1	-	18.5	0.14	-	0	0.25	1.27
7-24-3	10/18-10/19	2 hrs.	-	114	-	0.39	240	5.88	3620	140	0	60	80	4.4	4.4	0	136	13	7.2	-	18.5	0.09	-	0.10	0.3	1.33
9-24-1	10/10-10/11	1/2 hr.	-	470	8.00	21.2	53800	84.6	215000	170	0	80	90	67.7	22.3	45.4	102	92	6.9	-	23.75	0.49	-	0.43	2.5	5.34
9-24-2	10/15-10/16	1/2 hr.	-	360	-	31.6	61400	82.6	160500	300	0	200	100	64	23.1	40.9	236	98	6.8	-	39.25	0.64	-	0.33	5.7	5.00
9-24-3	10/18-10/19	1/2 hr.	-	290	-	24.4	32900	90.3	122000	360	0	200	160	65.6	28.5	37.1	294	110	7.2	-	36.75	0.46	-	0.52	5.8	6.69

(3) Gauge destroyed, Estimated from stage and current meter calibrations.
(4) Estimated from differences in flows from South Branch and North Branch at Paw Paw.

Table A-2

Daily Mean Discharges (cfs) at Upper Potomac River Stations,

September - October, 1956

Stream		North Branch Potomac River					Potomac River	Savage River		Georges Creek	New Creek	Wills Creek	Patterson Creek	South Branch Potomac River
Location														
Date		Steyer, Md.	Kitzmiller, Md.	Luke, Md.	Pinto, Md.	Cumberland, Md.	Paw Paw, W.Va.	Barton, Md.	Bloomington, Md.	Franklin, Md.	Keyser, W.Va.	Cumberland, Md.	Headsville, W.Va.	Springfield W. Va.
Sept.	10	25	82	195	249	359	808	16	123	24	5.6	102	18	244
	11	26	148	204	238	336	735	15	135	24	15	96	17	213
	12	39	190	377	392	417	721	15	121	24	22	92	72	267
	13	30	128	270	349	461	952	14	121	21	11	82	38	230
	14	22	108	219	279	359	815	11	121	18	8.0	74	26	217
	15	24	100	210	256	359	714	12	121	26	10	111	23	209
	16	44	152	253	304	568	928	22	121	41	14	220	33	221
	17	44	143	295	349	528	1070	18	121	28	11	165	31	213
	18	66	196	316	326	479	976	14	121	24	15	142	33	272
	19	37	124	274	363	485	976	11	121	20	11	123	27	317
	20	32	101	222	279	406	944	11	121	21	9.2	114	24	244
	21	30	90	210	252	354	778	10	121	18	8.0	101	20	230
	22	25	80	195	238	326	687	8.8	119	18	7.3	92	19	200
	23	25	108	207	224	308	635	8.2	119	17	6.8	86	18	192
	24	37	128	236	245	312	617	11	119	17	6.6	87	17	200
	25	34	128	260	259	336	648	8.2	119	15	6.3	82	16	213
	26	24	108	228	263	336	654	7.7	119	14	6.0	73	15	200
	27	31	120	232	256	326	674	7.7	119	18	10	71	18	205
	28	60	247	389	344	380	749	10	117	25	16	72	37	244
	29	46	183	365	447	510	890	8.8	117	18	11	71	37	272
	30	40	143	295	300	428	960	8.2	117	16	9.5	68	30	312
Oct.	1	32	124	260	300	364	882	7.2	117	15	8.4	61	25	302
	2	26	113	239	275	336	763	6.6	117	14	7.7	58	22	253
	3	24	110	228	263	321	687	6.2	117	14	7.3	57	21	226
	4	60	282	345	322	428	815	17	117	40	32	108	67	302
	5	64	338	580	668	762	1470	20	117	31	23	128	137	454
	6	60	374	490	545	691	1610	17	116	28	30	98	83	371
	7	190	692	923	879	939	1380	35	116	36	43	132	102	366
	8	108	464	734	940	1220	1800	34	116	29	29	138	78	322
	9	66	363	571	691	896	1560	27	116	24	20	125	55	292
	10	54	318	508	592	746	1300	21	116	21	16	114	42	272
	11	47	295	472	540	661	1150	17	116	19	14	101	37	244
	12	42	283	454	508	610	1050	14	116	18	13	92	32	221
	13	40	270	441	493	582	1000	13	116	17	12	87	30	213
	14	37	261	429	472	562	944	11	114	17	11	80	27	205
	15	34	206	385	457	541	905	10	114	16	10	76	25	196
	16	31	135	295	368	467	868	9.4	114	15	9.9	69	24	192
	17	31	124	253	300	390	756	8.8	114	15	9.2	67	23	184
	18	30	122	246	284	354	674	14	114	15	9.2	66	22	180
	19	28	124	242	275	345	648	13	112	14	8.8	65	21	176
	20	26	110	239	271	336	629	12	112	14	8.4	61	21	173
	21	28	103	213	259	326	617	8.8	112	14	8.0	60	21	173
	22	36	115	236	259	312	605	7.7	119	15	10	60	22	173
	23	68	190	312	292	350	617	11	112	20	14	66	26	180

Table A-3

Hourly Discharges at Times of Composite Sampling

Date, Time	Discharges (cfs) No. Br. at Luke	Discharges (cfs) Savage R. at Bloom.
10.10. 6 P	494	116
7	494	"
8	490	"
9	490	"
10	486	"
11	486	"
12	486	"
10.11. 1 A	481	"
2	481	"
3	481	"
4	481	"
5	476	"
6	476	"
7	476	"
8	476	"
9	472	"
10	472	"
11	472	"
12	472	"
1 P	468	"
2	468	"
3	468	"
4	468	"
5	468	"
6	463	"
7	463	"
8	463	"
9	463	"
10	463	"
11	458	"
12	458	"
10.12. 1 A	458	"
2	458	"
3	458	"
4	458	"
5	458	"
6	458	116

Date, Time	Discharges (cfs) No.Br. at Luke	Discharges (cfs) Savage R. at Bloom
10.14.12 P	417	114
10.15. 1 A	417	"
2	417	"
3	417	"
4	417	"
5	413	"
6	413	"
7	413	"
8	413	"
9	413	"
10	413	"
11	409	"
12	409	"
1 P	401	"
2	385	"
3	373	"
4	358	"
5	351	"
6	340	"
7	337	"
8	334	"
9	334	"
10	330	"
11	330	"
12	330	"
10.16. 1A	330	"
2	330	"
3	326	"
4	326	"
5	326	"
6	326	"
7	323	"
8	320	"
9	316	"
10	306	"
11	298	"
12	292	"
1P	284	"
2	278	"
3	274	"
4	270	"
5	267	"
6	264	114

Date, Time	Discharges (cfs) No.Br. at Luke	Discharges (cfs) Savage R. at Bloom.
10.16. 7 P	264	114
8	260	"
9	260	"
10	260	"
11	260	"
12	260	"
10.17. 1 A	256	"
2	256	"
3	256	"
4	256	"
5	256	"
6	256	"
7	253	"
8	253	"
9	253	"
10	253	"
11	253	"
12	253	"
1 P	253	"
2	253	"
3	253	"
4	250	"
5	250	"
6	250	"
7	250	"
8	250	"
9	250	"
10	250	"
11	250	"
12	250	"
10.18. 1 A	250	"
2	250	"
3	250	"
4	250	"
5	250	"
6	246	"
7	246	"
8	246	"
9	246	"
10	246	"
11	246	"
12 A	246	114

Date, Time	Discharges (cfs) No. Br. at Pinto
10.20.12 P	271
10.21. 1 A	271
2	271
3	271
4	271
5	271
6	271
7	267
8	267
9	263
10	263
11	259
12	256
1 P	256
2	256
3	252
4	252
5	252
6	252
7	252
8	252
9	252
10	252
11	252
12	252
10.22. 1 A	252
2	252
3	252
4	252
5	252
6	252
7	252
8	252
9	252
10	252
11	252
12	252

TABLE A-4

pH AND ACIDITY ON THE NORTH BRANCH ABOVE LUKE,
BELOW CONFLUENCE OF THE SAVAGE RIVER.*

		JAN.		FEB.		MAR.		APR.		MAY		JUNE		JULY		AUG.			SEPT.		OCT.		NOV.		DEC.	
1949	Day	12		9		9		6	20	4	18	1	15	6	20	3	17		7	21	5	19	16		14	
	pH	4.5		4.5		4.5		4.9	4.4	4.1	4.0	4.0	3.5	3.9	4.7	3.7	3.6		3.7	3.6	3.6	3.8	4.6		5.1	
	Tot.Acid.	7.5		8.0		9.5		9.0	-	18	18	17.0	50	16	8.0	36.0	35.0		37.0	54.0	55.0	30.0	13.0		6.0	
	Tot.Alk.	-		-		-		-	-	-	-	-	-	-	-	-	-		-	-	-	-	-		-	
	Discharge	1015		1311		883		820	605	256	206	258	86	266	538	119	174		133	98	76	111	308		1306	
	NB	796		976		640		568	475	190	156	204	69	218	430	94	154		111	87	66	90	262		846	
	SR	219		335		243		252	130	66	50	54	17	48	108	25	20		22	11	10	21	46		460	
1950	Day	11		15		15		5	19	3	17	7	21	5	19	2	16		6	20	4	18	15		13	
	pH	4.8		5.3		6.0		4.7	4.4	5.2	6.2	5.1	4.9	4.2	4.5	4.6	3.7		4.0	5.0	5.1	5.4	6.4		5.9	
	Tot.Acid.	11.0		12.0		3.5		-	13.0	2.0	-	4.5	6.0	19.0	11.0	12.0	30.0		13.0	9.0	9.0	5.0	8.0		3.0	
	Tot.Alk.	-		-		-		-	-	4.0	7.0	-	-	-	-	-	-		-	-	-	-	-		-	
	Discharge	1164		1885		1840		886	377	2335	1294	457	461	140	180	161	60		73	90	121	126	354		1170	
	NB	888		1200		1340		689	292	1710	905	376	410	120	155	128	52		50	64	90	100	172		805	
	SR	276		685		500		197	85	625	389	81	51	20	25	33	7.6		23	26	31	26	182		365	
1951	Day	20		20		14		4	18	2	16	9	23	5	18	1	15		5	19	3	17	7	21	5	19
	pH	5.9		4.9		4.9		4.5	4.4	4.9	5.2	3.5	4.0	3.8	3.2	3.3	3.2		3.1	3.2	3.2	3.2	3.7	3.5	3.7	3.7
	Tot.Acid.	-		-		-		-	-	-	-	-	-	-	-	-	-		-	82	88	61	57	72	54	30
	Tot.Alk.	-		-		-		-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-
	Discharge	2140		1380		914		1600	1290	1290	875	250	881	295	184	65	57		54	59	43	43	74	58	278	300
	NB	1756		935		533		1184	870	917	528	195	721	236	183	64	49		46	32	35	32	66	50	268	291
	SR	384		445		381		416	420	373	347	55	160	59	1.0	1.2	8.1		8.1	27	8.1	11	8.4	8.4	9.9	9.2
1952	Day	2	16	6	20	5	19	2	16	7	12	4	18	2	16	6	20								3	17
	pH	5.9	4.0	6.2	4.3	3.7	4.1	3.9	4.7	6.0	6.7	4.4	3.7	3.7	3.8	5.1	3.7								6.1	5.6
	Tot.Acid.	12	19	-	4.6 21.4	21	17.8 1.8	7.0	-	-	-	11.4 0.9	14.5	8.2	28.2	-	38.7 15.4		---------- No Data ----------						-	17.0
	Tot.Alk.	-	-	11	-	-	-	-	1.3	5.5	7.0	-	-	-	-	4.5	-								10.5	
	Discharge	3450	725	1660	431	484	1160	563	1300	1640	1010	300	146	106	84	78	81								155	352
	NB	3363	714	1174	365	475	1147	551	1131	1156	798	226	79	52	41	30	52								57	257
	SR	87	11	486	66	8.8	13	12	169	484	212	74	67	54	43	48	29								98	95
1953	Day	7	21	4	18	4	18	1		6	20	3	17	1	15	5	19		2	16	7	21	4	18	5	19
	pH	4.9	6.3	4.3	6.2	4.1	4.3	4.4		4.4	5.1	5.9	3.8	3.6	4.3	3.8	3.9		4.7	4.3	6.9	3.9	3.9	4.7	4.3	3.9
	Tot.Acid.	-	-	-	-	18.6 3.1	11.4 1.7	12.3 8.8		-	-	-	13.2	22.0	-	8.0	8.0		-	-	-	38 7.5	33.5 6.0	-	-	27.0 6.0
	Tot.Alk.	4.0	6.0	3.5	6.0	-	-	-		2.2	3.5	5.0	-	-	0	-	-		3.0	0	17.0		-	2.5	0	-
	Discharge	146	2167	815	1162	1612	1310	1039		984	1040	459	102	88	91	96	95		95	95	91	93	91	91	91	
	NB	52	1108	720	697	1514	1211	929		929	855	298	71	72.5	25	28	43		31	20	8	33	40	34	51	
	SR	94	1059	95	465	98	99	110		55	185	161	31	15.5	66	68	52		64	75	83	60	51	57	40	
1954	Day	6	20	3	17	3	17	7	21	5	19	2	16	7	21	4	18		1	15	6	20	3	17	1	15
	pH	3.6	4.1	5.0	4.0	6.5	4.5	3.7	3.9	3.7	3.9	3.9	5.1	3.5	3.6	3.7	4.1		5.1	3.7	3.9	6.5	5.0	4.7	6.3	4.5
	Tot.Acid.	48.5 14.5	21.0 4.5	-	17.0 4.0	-	-	25.0 9.5	18.5 5.5	22.5 9.0	19.0 7.0	18.0 10.0	-	43.5 16.5	43.5 26.0	29.5 11.5	12.5 2.5		-	30.0 10.0	22.5 6.0	-	-	-	-	-
	Tot.Alk.	-	-	3.0	-	5.5	0	-	-	-	-	-	2.0	-	-	-	-		2.5	-	-	5.0	2.0	2.0	7.0	0.5
	Discharge	99	484	291	612	3180	1060	462	609	397	426	566	598	102	181	370	667		454	141	233	1350	566	391	1540	806
	NB	88	413	208	604	1370	976	451	598	385	414	490	457	85	169	312	638		350	78	136	1074	469	296	996	719
	SR	11	71	83	8.5	1810	84	10.7	11.2	11.8	12.1	76	141	16.7	12.1	58	29		104	63	97	276	97	95	544	87
1955	Day	5	19	2	16	2	16	6	20	4	18	1	15	20		3	17	31	14	21	5	19	2	16	7	21
	pH	5.4	4.1	4.1	4.8	6.1	4.3	4.0	3.9	3.9	4.0	3.7	4.4	3.7		4.9	4.3	5.0	5.8	4.7	5.7	5.0	5.1	4.2	5.2	5.8
	Tot.Acid.	-	20.0 4.0	24.5 5.5	-	-	14.5	22.0	18.0	20.0	15.5	24.5	15.0	20.0 2.0		-	-	-	-	-	-	-	-	-	-	-
	Tot.Alk.	2.5	-	-	0.5	3.0	-	-	-	-	-	-	-	-		1.0	3.0	1.0	3.5	0.5	3.5	1.5	1.5	3.5	1.5	3.0
	Discharge	1710	428	405	719	3490	984	321	349	426	479	203	1170	121		104	853	347	186	288	110	124	104	219	257	153
	NB	1214	345	364	668	2480	899	310	337	412	404	156	960	89		39	152	245	83	206	37	55	51	210	210	67
	SR	496	83	41	51	1010	85	11	12	14	75	47	210	32		65	701	102	103	82	73	69	53	9.1	47	86

* Data obtained by the West Virginia Pulp and Paper Company.